VOL. XXXVIII. No. 12 DECEMBER, 1960

THE STRUCTURAL ENGINEER

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The Structural Engineer in the Coal Industry
by C. A. C. Davies

Recent Engineering Work at the Building Research Station

Brinsworth Steel Strip Mill
Discussion on the Paper by Donovan H. Lee (Member), G. O. Kee and N. Lancaster

New Developments in Structural Analysis and Design by Means of the Electronic Computer
Discussion on (1) Application of an Electronic Computer to Structural Steel Design,
by L. Morgan

(2) Analysis of Grid Frameworks and Floor Systems by the Electronic Computer,
by Dr. E. Lightfoot (Member) and F. Sawko

(3) Elastic Critical Loads of Multi-Bay Pitched Roof Portal Frames with Rigid External
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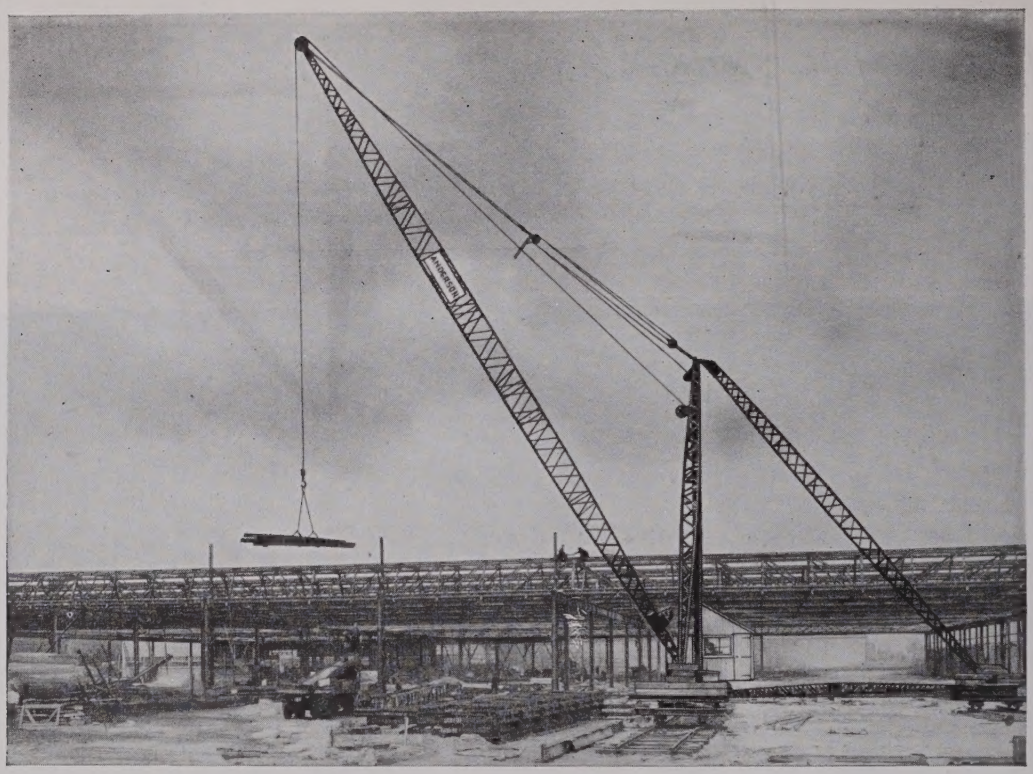

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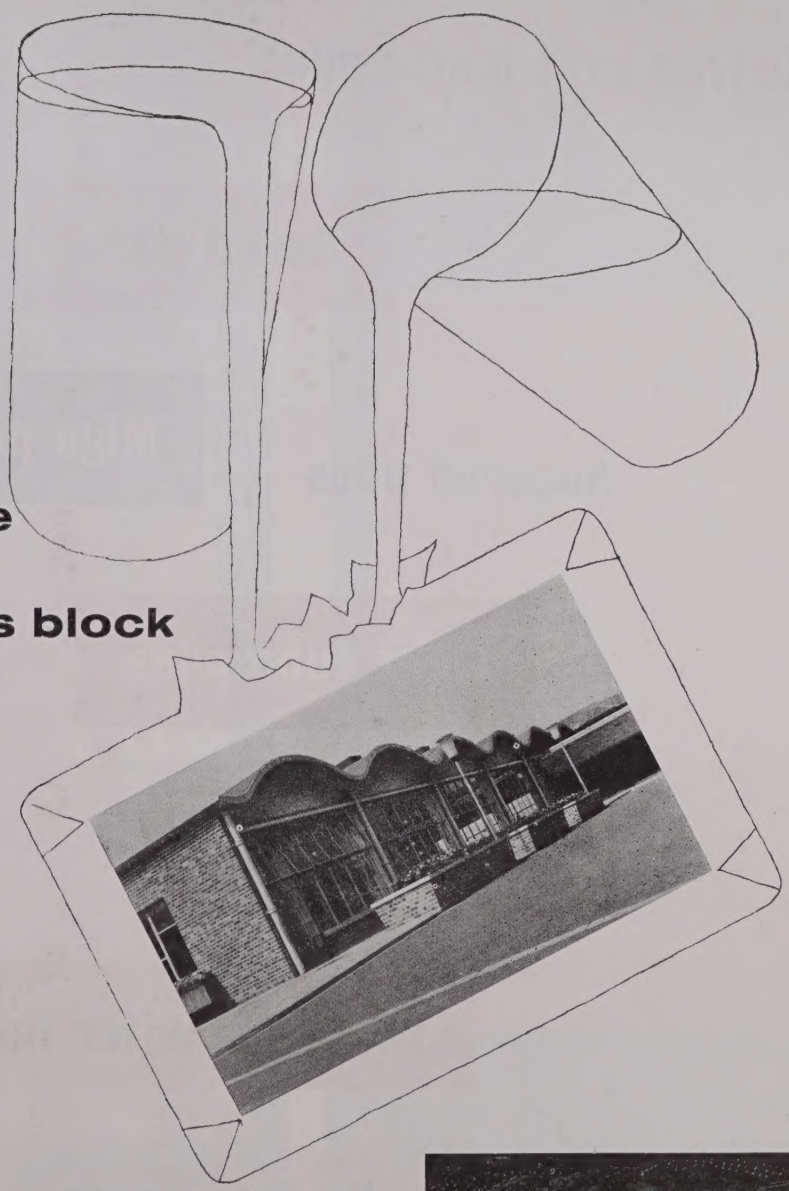

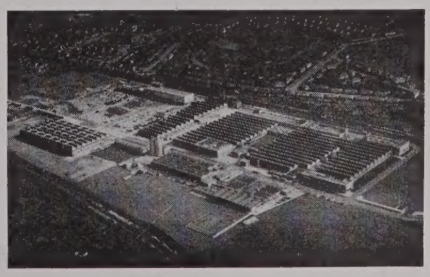

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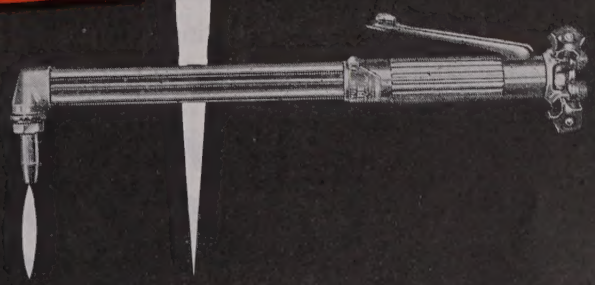

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Auckland Star photograph of the 4 million gallon reservoir under construction

St. John's Reservoir constructed for the Auckland City Council, is a circular prestressed concrete structure of four million gallons nominal capacity. The internal diameter is 180 ft., and the height from floor to underside of roof beams 25 ft. 8 ins. Depth of excavation over the site averaged 7 ft. The reservoir is founded on firm clay. Further details of this unusual application are available on request.

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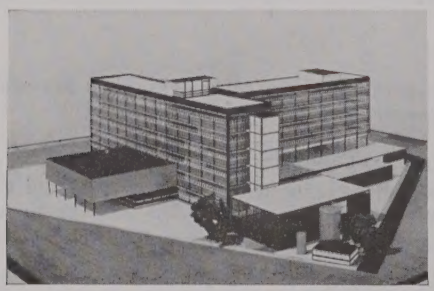

West's Shell Piles, 17½" and 20" diameter, driven up to 50 ft. through a former gravel pit to the underlying stratum of London clay, support this new building at Carnwath Road, Fulham, at present under construction for the North Thames Gas Board. When completed next year, the premises will house research units, administrative services, and an electronic computer centre.

This is a typical application of the modern, mobile, West's Shell Piling System which combines a pre-cast sectional outer shell, driven to a set in the load-bearing stratum, with a reinforced concrete core cast-in-situ after driving is completed. In this way, the solid effect of the positively driven pile is maintained without fatigue in the pile core—a double assurance of stability for the designers of many types of structure.

Model photograph, by Leonard Smith, by courtesy of the North Thames Gas Board and E. R. Collister and Associates. Architects & Consulting Engineers. Model commissioned by the Morris Singer Co. Ltd.

Site photograph, by Photo Reportage Ltd., by courtesy of Pierhead Limited.

Main Contractor : Trollope & Colls Limited.

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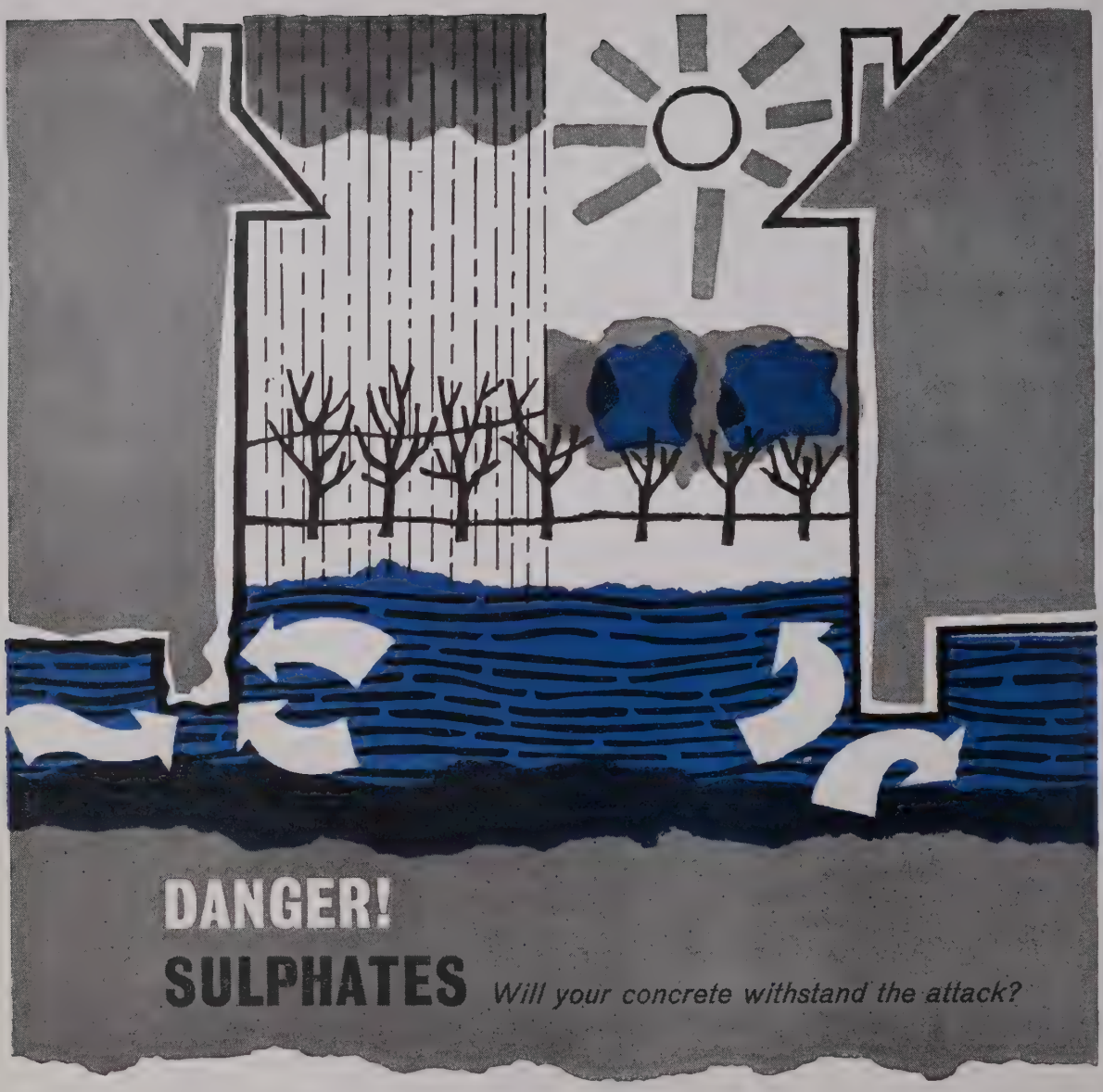

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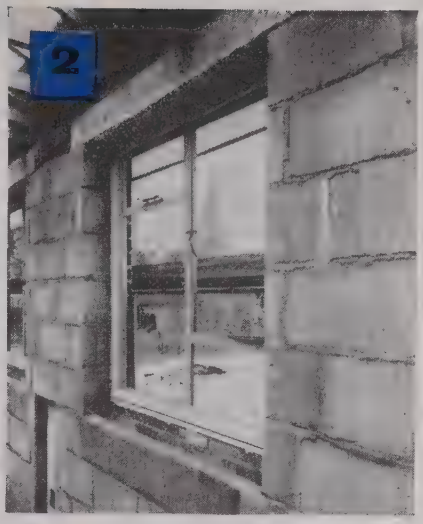

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2 The photograph shows the neat returns to the reveals, typical of Thermalite construction. No special Corners or Closers are necessary; Thermalite Blocks are readily and accurately sawn. Note how easily the hot air ducting has been accommodated.

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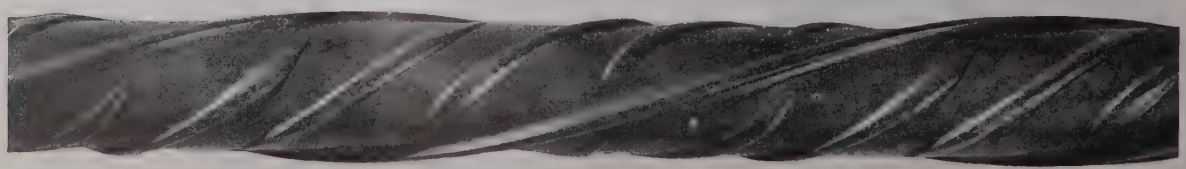

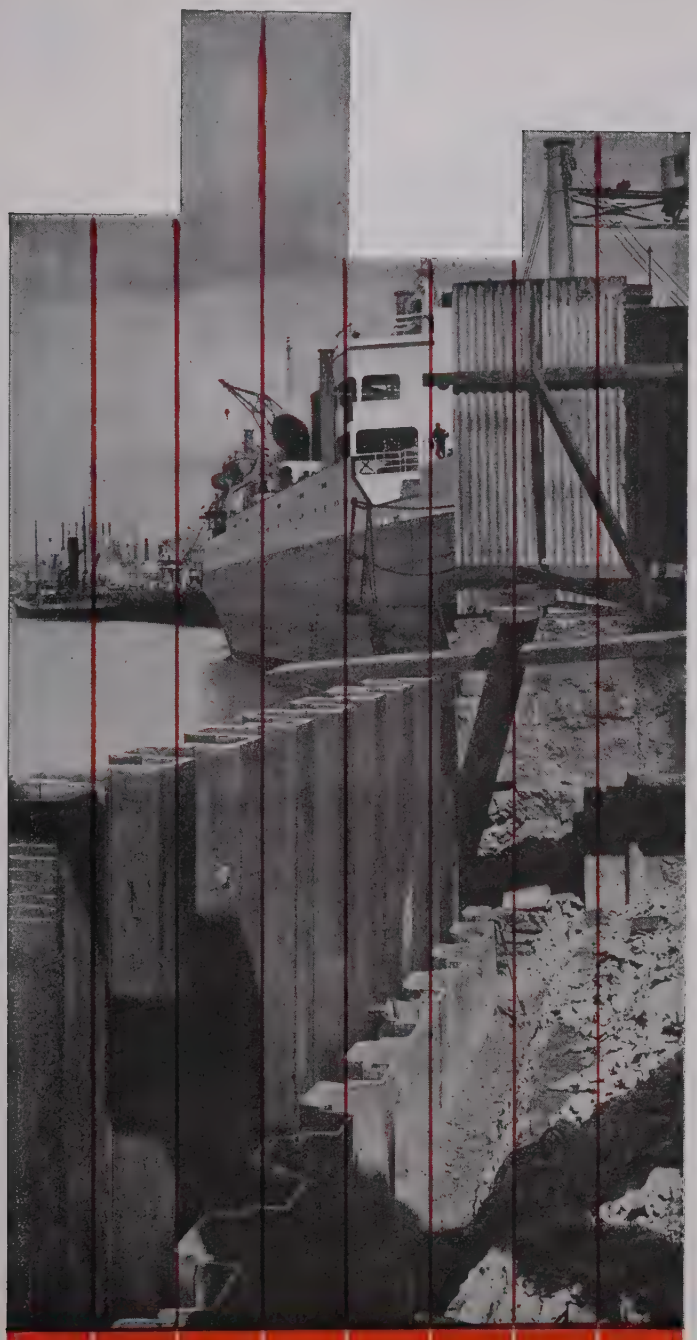

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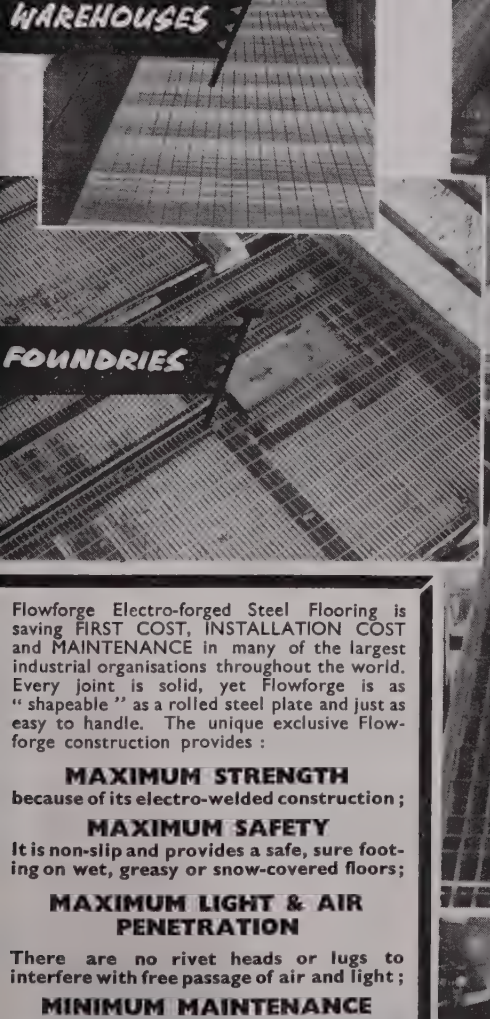

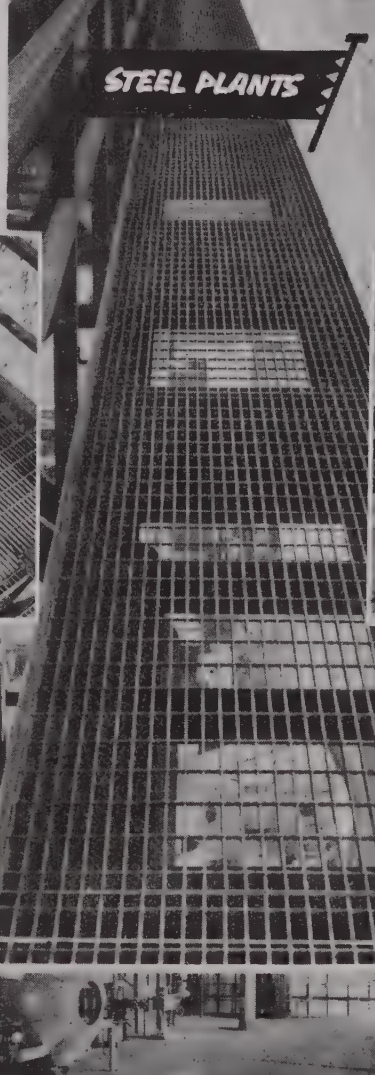

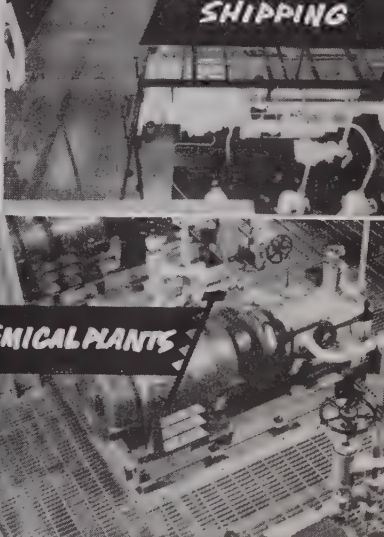

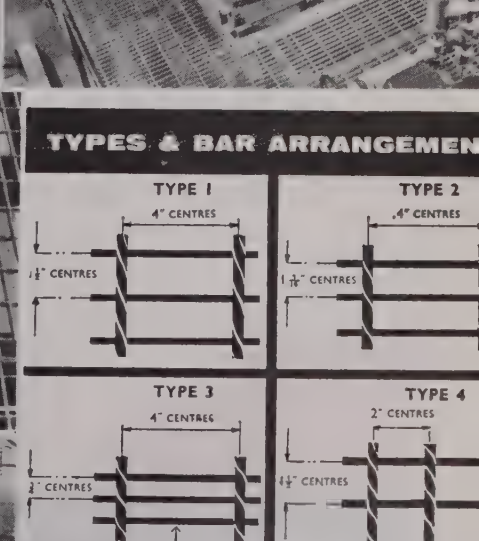

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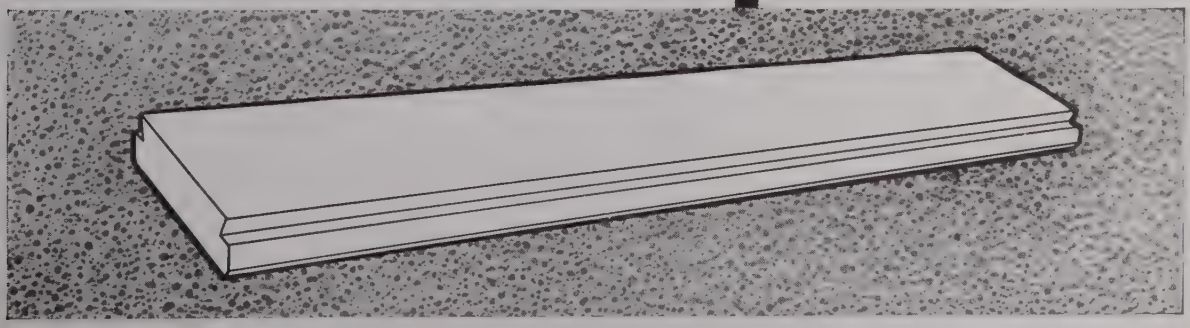

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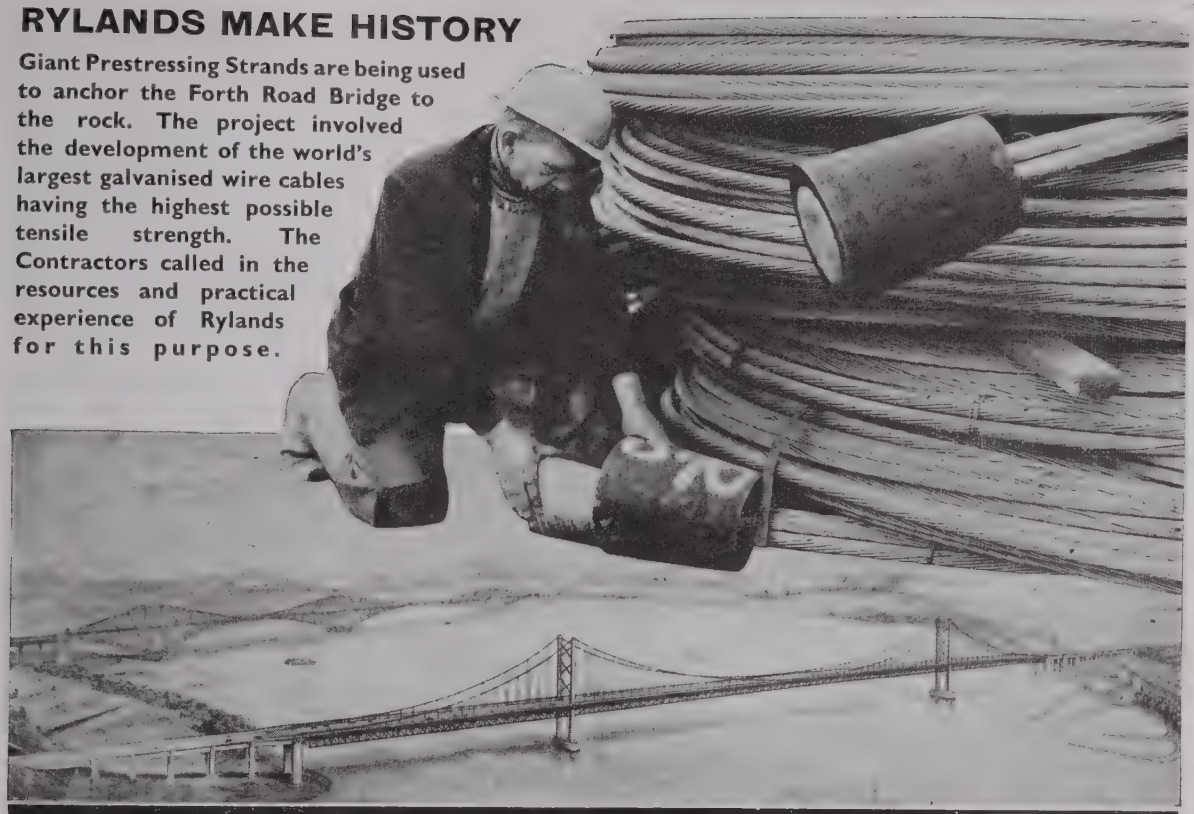
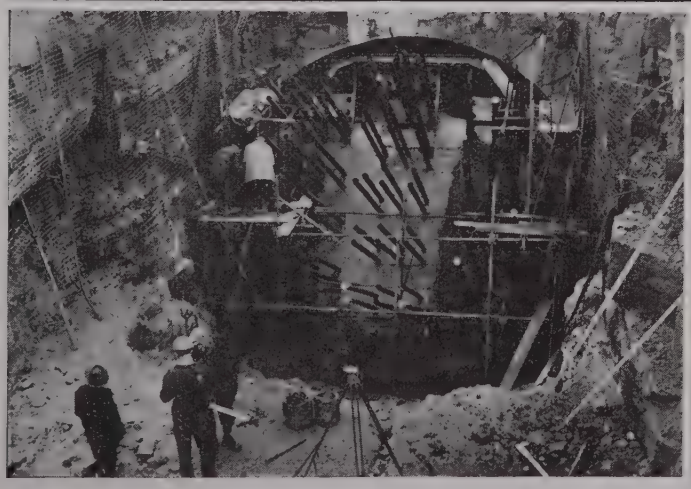


Forth Road Bridge Anchorages



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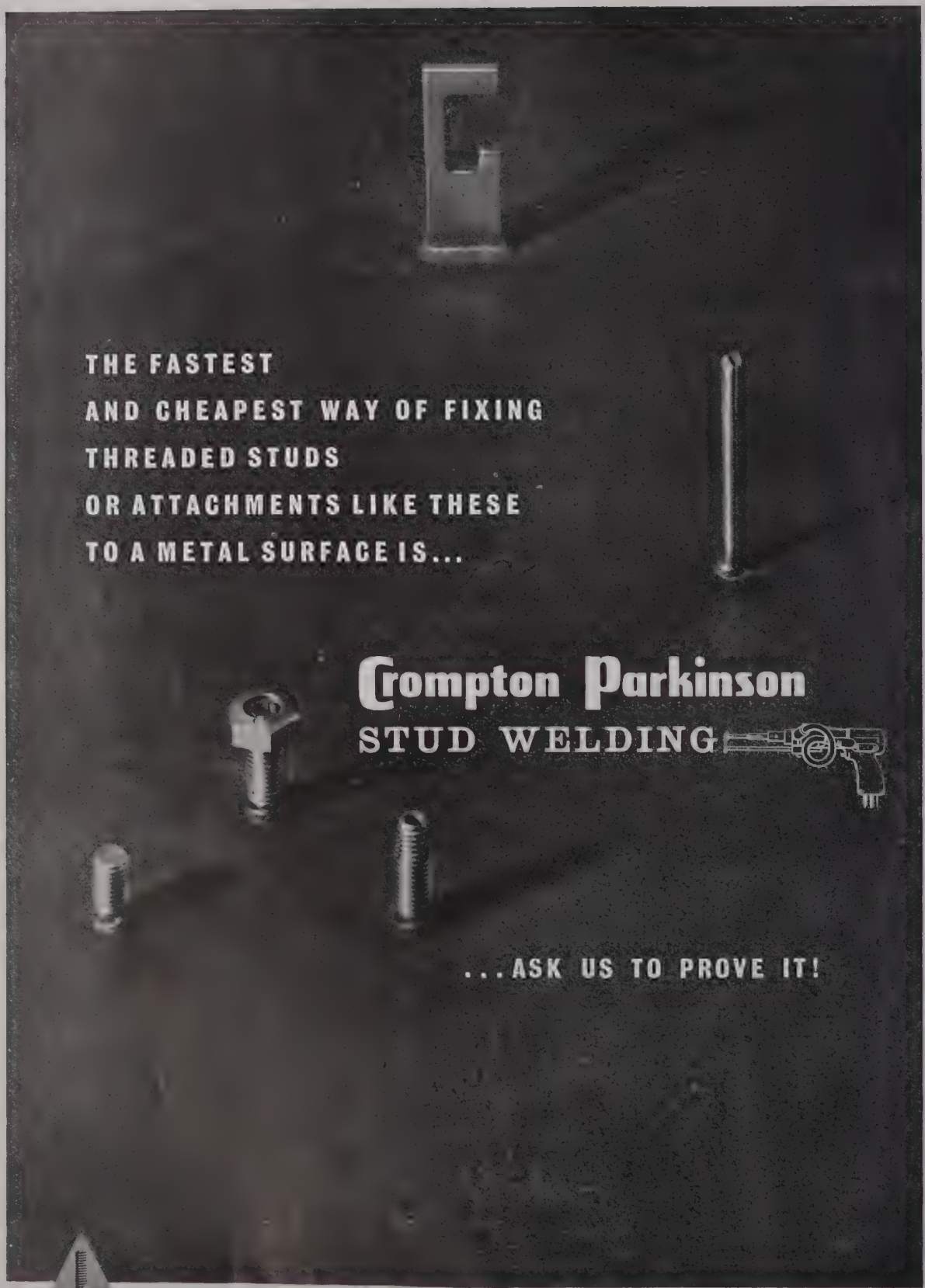
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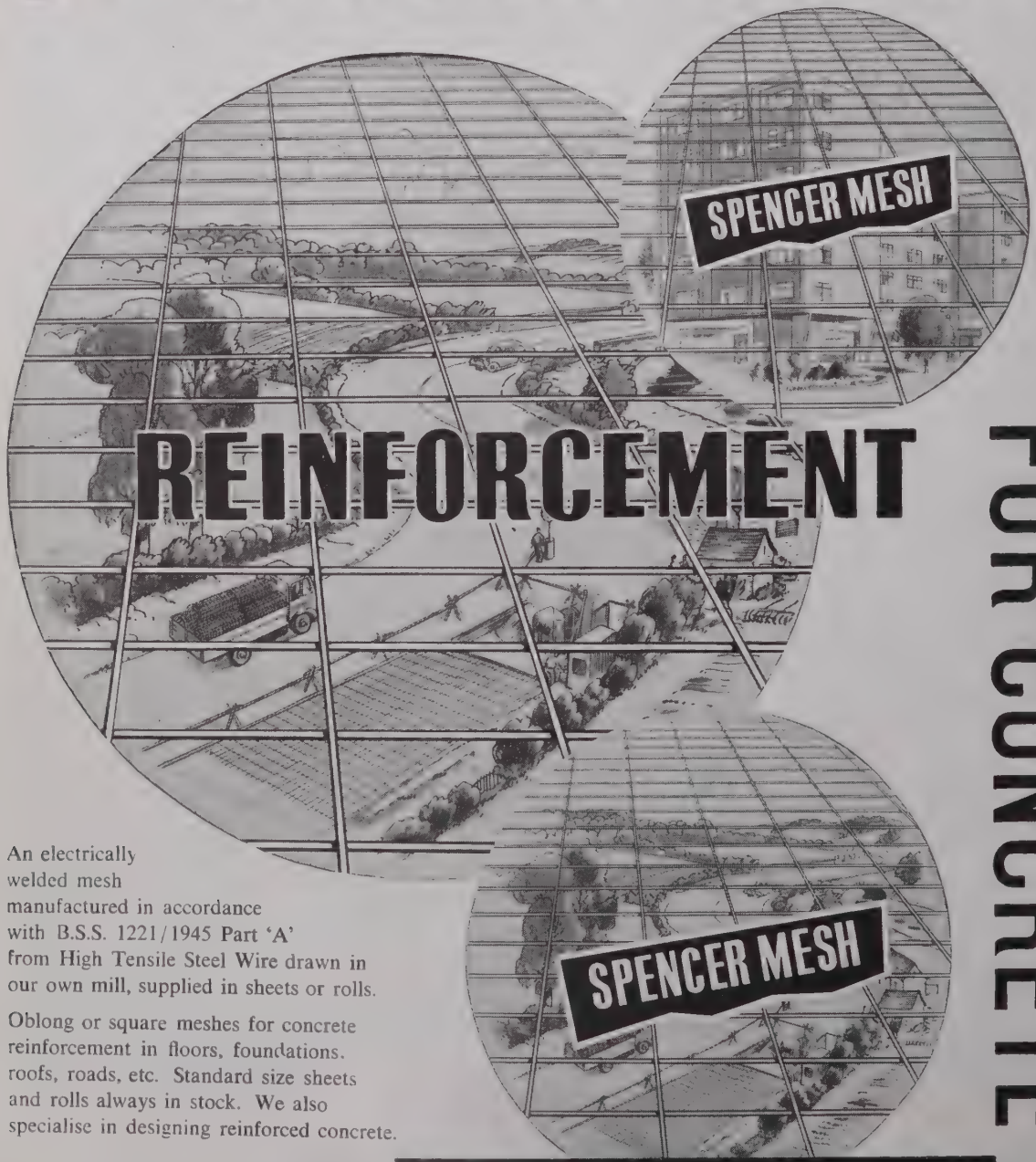

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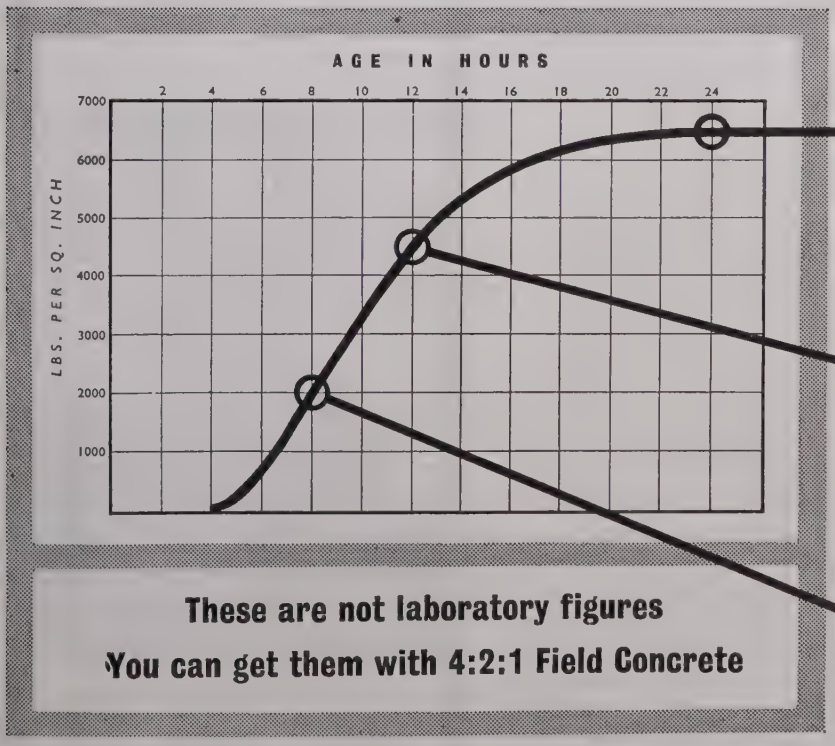

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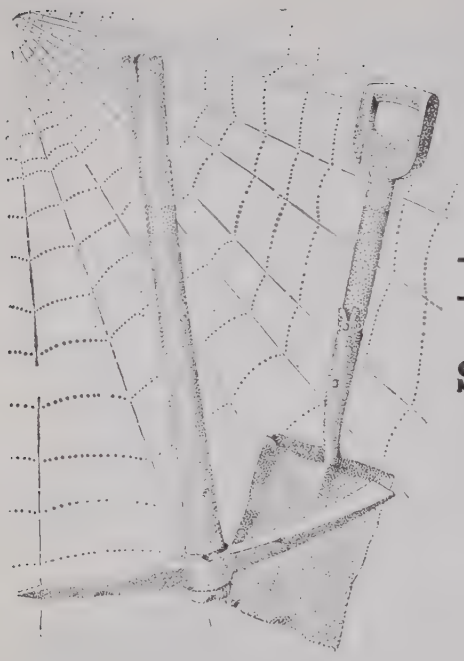

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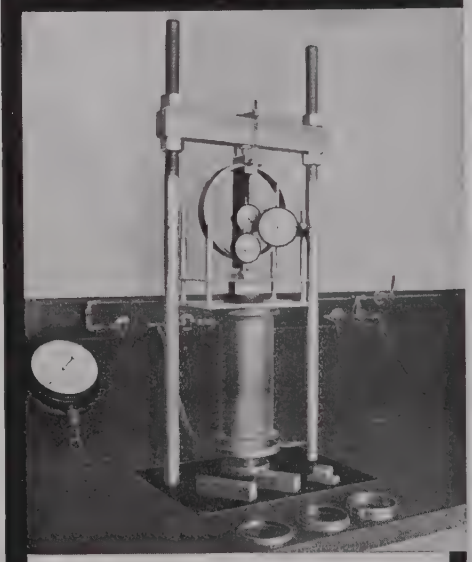

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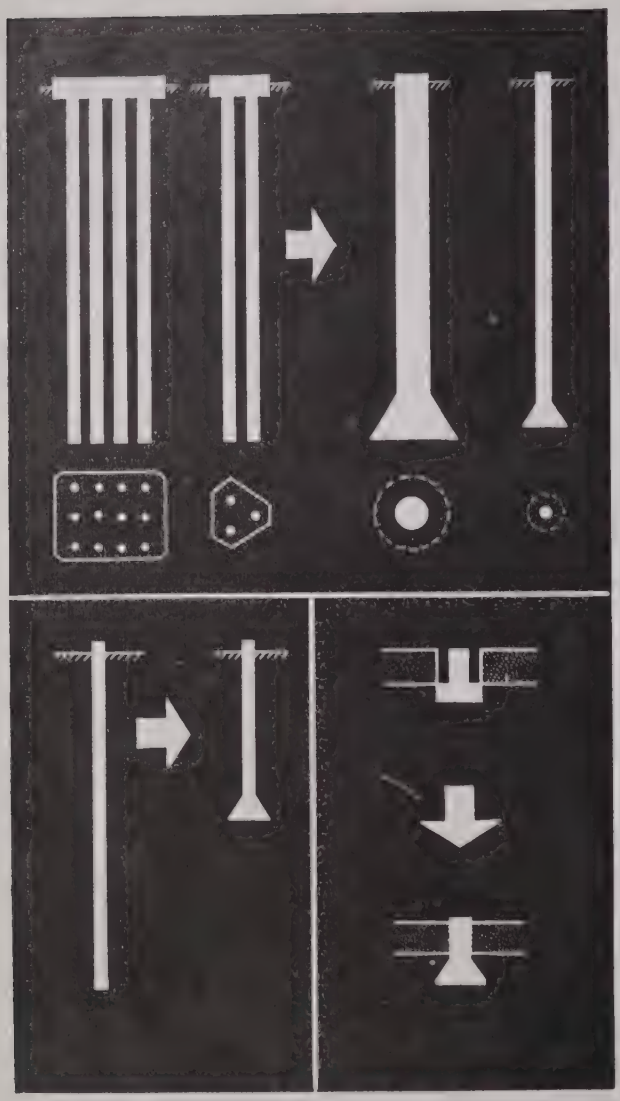

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The Structural Engineer in the Coal Industry *

by C. A. C. Davies, M.I.C.E.

Synopsis

A brief historical reference is made particularly relating to structural developments. The main design features of headframes and winder towers and the principal colliery buildings are discussed. Reference is made to some design and constructional aspects of shaft linings, insets, skip pockets and underground roadways.

Introduction

The history of the development of the Coal Industry makes a fascinating study because it is so closely bound up with the social, economic and engineering development of this country from the 16th Century onwards.

In the 16th Century when more coal was needed than could be obtained from the gleaning of sea coal from coastal outcrops and from the small drifts and surface excavations which followed, shallow pits were sunk and a hand windlass used to raise the coal. In 1650, a Cog and Rung Gin was introduced followed by the Whim Gin towards the end of the 17th Century. Both were horse driven and it was not until 1763 that Newcomen's fire engine was used to raise coal, but due to the difficulty which existed at that time of imparting a rotary motion to the machine, this was not a success, and it was not until Watt's rotative steam engine was commissioned in 1784 that mechanical winding of coal and men was firmly established. But though the horse was displaced by machinery at the pit-top, it was to be another 60 years before the pit pony took the place of women and girls in the haulage of coal below ground.

From this beginning and from other developments, such as the introduction of the wire rope in 1849, great strides were made in winding. The pit-top structure grew correspondingly from what were little more than timber shear legs to the pitch-pine headframe erected at Florence Colliery in 1878. This structure was 55 feet high from ground level to the centre of the 16 foot diameter pulleys. The back legs were 68 feet long and splayed 27 feet at the bottom.

Sometimes the headframes were built as somewhat massive brick towers combined with the heapstead building and later, with the growing production of iron and its increasing use as a constructional material, it was employed in the construction of headframes. But iron was soon supplanted by steel. The earliest reference to the use of this material that the author can trace is in 1906. At about that time two lattice steel headframes were erected in the North Staffordshire coalfield. The date of the first use of reinforced concrete for this purpose is uncertain, but there is a record of a reinforced concrete headframe and screening building being built at Arley Colliery in Warwickshire in about 1925.

And so the carpenters, bricklayers and stonemasons who had been the mastermen of the surface buildings at the old pits began to give place to the new men with new techniques of design and construction.

The coal which was brought up the shaft was heaped on to the floor of a building built around the headframe and which from this practice became known as the 'Heapstead'—a name which still persists today though its original purpose has changed beyond recognition. Today the heapstead is a building housing the mine car circuits by means of which the full cars are mechanically propelled from the pit cages, emptied at a mine car tippler pit and finally returned to the shaft in what is virtually a continuous operation. Alternatively, at shafts where the coal is brought up in skips, it will house the skip discharge equipment and storage hoppers. From this pit-top building the raw coal with its admixture of dirt from the workings, will be taken by a conveyor belt system supported on gantries to the high level storage bunkers of a coal preparation plant where it will be screened, washed and finally graded into its various sizes and qualities according to marketing requirements. At this point it may be discharged directly into railway wagons or again transported by conveyor gantries to storage bunkers for discharge into lorries, or in the case of some Tyneside Collieries, to coaling staithes for loading into ships or barges.

With the coal brought up the shaft there will be a certain amount of dirt, the proportion depending very largely upon seam thickness and to some extent upon the mining methods employed. This dirt must be removed and prepared by crushing and screening or sometimes by screening only and returned to the pit bottom for stowing into the cavities left by the extraction of the coal.

Below ground is another world of continuous construction and maintenance, not only of plant and equipment, but of roadways and drivages and all the materials for this endless variety of works must find its way from the colliery workshops and stores to the shaft and then underground.

A modern pit will employ between 2,500 and 3,000 men producing about 4,000 tons of coal per day. Before the miners go into the pit they will require facilities for changing into pit clothes and upon their return off shift they will require to bathe and change back into ordinary attire. The pithead baths building is one of the largest and not the least important at the pit.

From this brief account it will be seen that today a coal mine presents a complex problem of handling men, materials and coal and the design of all the buildings and structures is directed to that purpose.

Headframes and Winder Towers

The design of a headframe and particularly of a winder tower, where all loads are carried within the structure, presents the most unusual problem to the structural engineer. There are many matters bearing on their design which are not commonly encountered elsewhere and for which there are no standard solutions, and there is very little published information on design.

* *Paper to be read before the Institution of Structural Engineers, at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 8th December, 1960, at 6 p.m.*

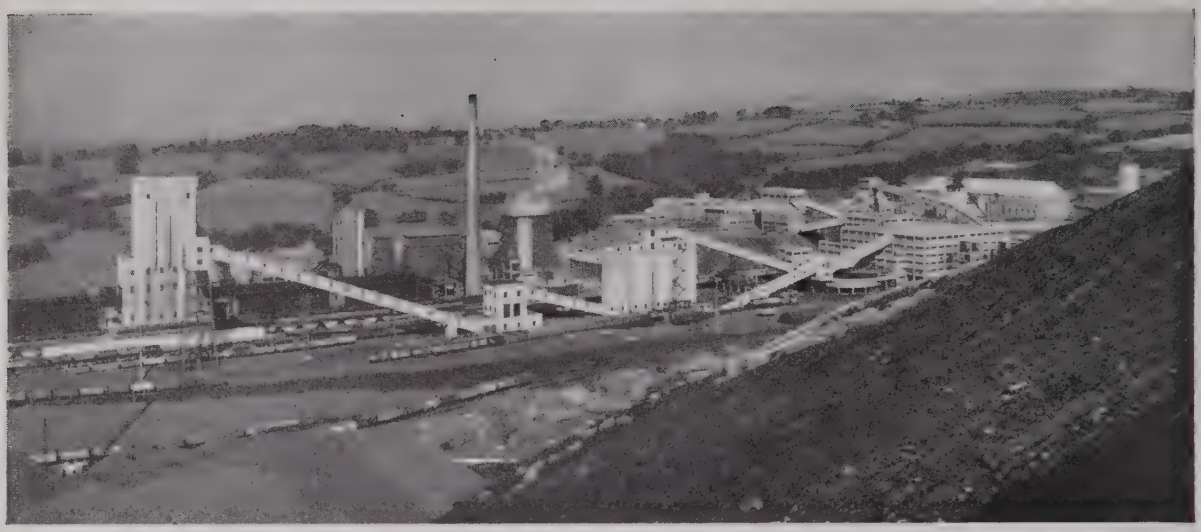

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Fig. 1.—Cwm Colliery and Coking Plant.

The following are some of the fundamental matters in which towers, and to a lesser extent, headframes, contrast with normal building structures :

(i) The principal loads are of great magnitude and are concentrated at only a few positions on the structure.

(ii) The ratio of live to dead load on the main members is unusually high.

(iii) The moving loads in the shaft are suspended by elastic steel wire ropes and are guided by rope or fixed steel guides either of which will produce frictional resistance, the magnitude of which it is difficult to calculate with any degree of certainty. The suspended system will have a varying frequency of oscillation depending upon the position of the conveyance in the shaft, and this will produce variations in the vertical load.

(iv) The dynamic nature of the loads and a certain degree of out-of-balance in rotating parts tend to induce vibrations in the structure and the natural frequency of the supporting framework must be examined in relation to these.

(v) Under normal operating conditions large impact loads may sometimes occur at the beginning and the end of a winding cycle.

(vi) The factors of safety of the ropes which transmit loads to the structures are higher than the comparable factors of safety of normal structures.

(vii) The stress-strain characteristics and strength of the steel of the winding ropes are quite different from those of the mild steel commonly used in structures.

(viii) Some types of winding machinery are very sensitive to differential deflections at their points of support. Others are relatively flexible.

(ix) Some conditions of loading occur very infrequently, such as those which occur during erection of tower-mounted engines, or when ropes are installed or changed.

Satisfactory solution to many of these problems can best be found only if the structural engineer has a very broad knowledge of the construction and working of the winding engines and if he is consulted at the earliest planning stages.

It has been shown that normal working loads are unusual and severe. Notwithstanding the high standard of mechanical and electrical safety devices, it is always prudent for the structural designer to take account of the very severe shock loadings that might occur as a result of an accident, particularly if 'rope-break' occurs.

To this end the structures should satisfy the following two design requirements :

(i) When all machinery is in position and working normally under maximum conditions of load, the stresses in the structural members should not exceed those recommended in the appropriate British Standards and Codes of Practice.

(ii) Under conditions of 'rope-break' or 'short circuit' in the motors, the stresses induced in the structural members may be allowed to exceed those referred to above, but must be less than those which would result in permanent strain or deformation of the principal structural members.

Sometimes the design problems are still further complicated by constructional difficulties at the site, particularly when headframes or towers have to be erected around and over existing heapstead buildings to avoid interfering with production, or around the sinking headframe at a new pit. This latter problem was forestalled to some extent at the Wolstanton No. 3 Tower by introducing an additional concrete platform below the deflector pulley floor to accommodate the sinking pulleys. Work on the tower was suspended temporarily at this point to allow the shaft sinkers to set up all their equipment and subsequently shaft sinking and the remainder of the tower construction proceeded simultaneously. At the new Kellingley Colliery this has very logically been carried a step further and the steel tower and guide

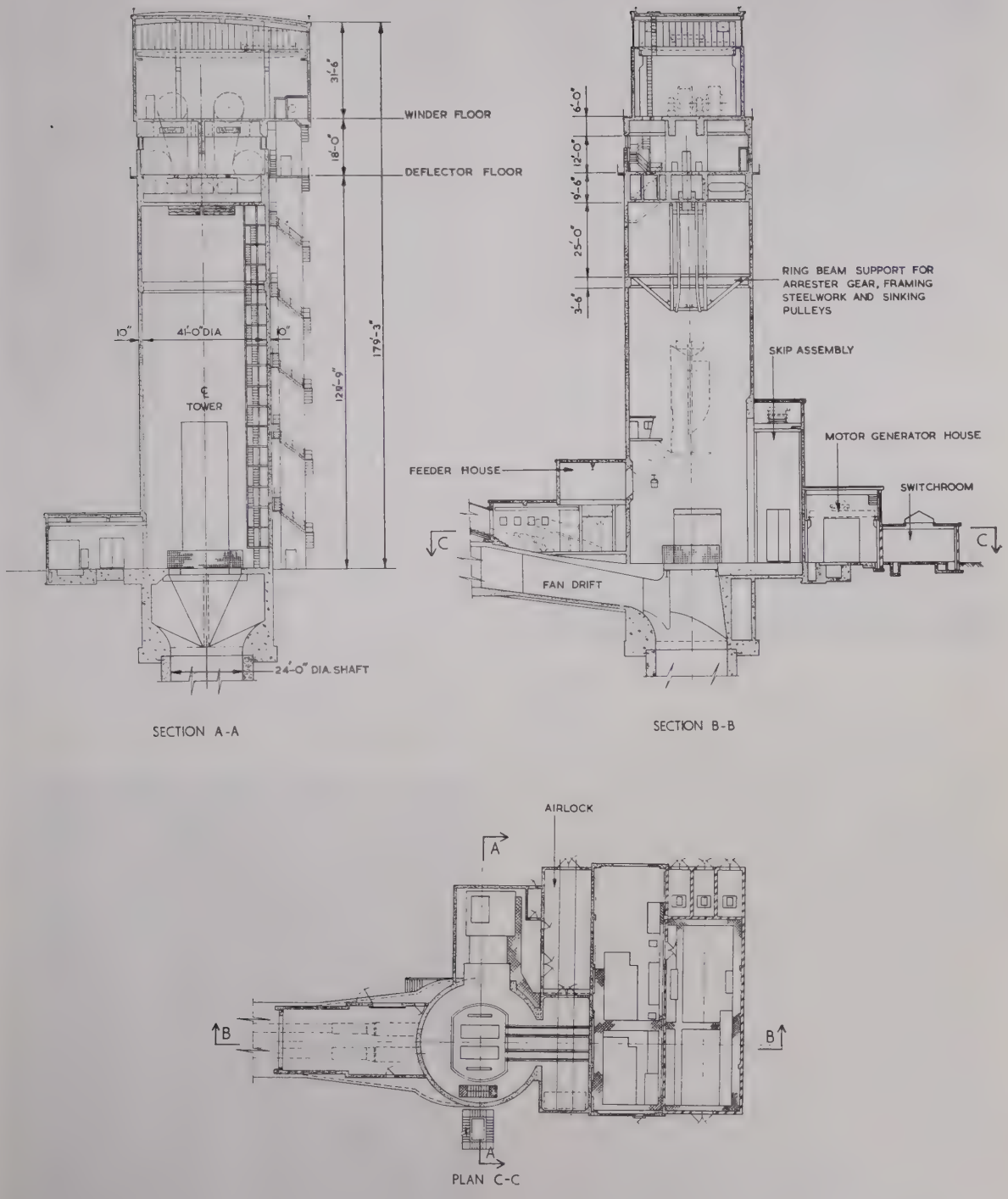

Fig. 3.—Crown shaft winder tower—Westoe Colliery.

Fig. 2.—Reinforced concrete headframe at Hucknall Colliery.

frame have been completed and the permanent winding engines installed in the tower so that they may be used for the shaft sinking operations. Minor modifications have been made to the tower and guide frame steelwork for this purpose.

(a) *Headframes*

These structures are used in conjunction with ground mounted winders which may be of the drum or Koepe (friction) type. They are characterised by the two large free running pulleys which they carry at the top. The winding engines are mounted at some distance from the frame, the distance being greater in the case of the drum winder than for the Koepe winder.

With drum winders it is usual for the pulleys to be mounted side by side so that the frames are also subjected to some torsion. With Koepe winders the pulleys are mounted one above the other and the continuous rope and the pulleys all lie in one plane so that torsion is avoided.

The tensions in the winding ropes tend to produce considerable overturning moments on the headframes and it is usual to resist this by providing an inclined strut or back-legs to transfer the forcee directly to the ground. In some cases the struts ars arranged in line with the inclined ropes so that there is no horizontal component of force exerted, but it is more usual to arrange the back-legs so that they coincide with the line of the resultant of the forces in the vertical and inclined ropes. In theory, at least, the whole of the live load forces are resisted by this strut and there should be no variation in the pressures beneath the vertical members of the frame. In this case the strut is shorter than in the previous case, but the direct force to be resisted is greater. Long raking struts have a natural tendency to vibrate and as headframes became taller and bigger, the lattice type of construction so frequently adopted led to great complexity in bracing. Today the use of large fabricated sections and the new Universal sections has eliminated complicated bracings and simplified the structures generally. The use of tubular members must obviously suggest itself, but so far headframes of this type have not been competitive in cost. Some headframes have been, or are about to be, constructed in reinforced concrete. Many of these have followed the traditional design of their steel counterpart, but the author believes that in this medium the most satisfactory and economic design is achieved with the box form of construction where the weight of the structure is combined with the inclined resultant, thus eliminating back-legs. Several headgears of this type have been built in the East Midlands Division of the Board. *Figure* 2 illustrates one of these recently completed at Hucknall Colliery in the East Midlands Division.

(b) *Winder Towers*

The general principles of friction winding have been outlined in other papers (Young, Metcalf and Longden, *Proceedings of the Institution of Civil Engineers*, Volume 6, April, 1957; Bridges, *The Structural Engineer*, Volume XXXII, No. 4, April, 1955, Husband), and it is not intended to repeat or enlarge upon them here.

There are many factors, mining, mechanical and economic which may influence the selection of a winding system and these are the province of the mining and winding engineers. The structural economics may have some bearing on the matter, but can rarely be a deciding factor.

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Fig. 4.—Crown shaft and tower—Westoe Colliery.

Broadly speaking, drum winding associated with the headframe can be done only with a single rope and the limiting rope size is about 2 in. to 2½ in. For pay loads and winding depths requiring a greater rope size than this, the winding engineer has to use more than one rope and adopt the principle of friction winding. For one or two ropes the winding engine and friction drum may be ground mounted, but if three or four ropes are needed, then they must be mounted in a tower directly above the shaft.

In this country there are now 57 friction winder towers either built or under construction. Thirty of this number are in structural steel and 27 in reinforced concrete.

The choice between the two mediums has been dictated generally by local preference based on site circumstances rather than on economics. The monolithic nature of a concrete tower has many attractions and the difficulties of building such a structure around an existing coal winding or shaft sinking headframe are not sufficient to warrant the rejection of concrete. Indeed, several concrete towers have been erected under these difficult conditions, notably at Dawdon Colliery. Concrete towers are, of course, much heavier than steel and the designer must consider the effect of this additional foundation load on an old shaft which may have a brick lining of somewhat dubious strength. Again foundations may have to be constructed in frozen ground or in ground which will later be frozen, and therefore subject to frost 'heave' and settlement upon thawing. In such cases where differential movements are almost a certainty, the advantages of the greater flexibility of a steel tower will be apparent. There is one other matter which may have a very direct bearing on the choice of structures. The winding tower on the upcast shaft is sometimes air-locked up to the bumping beam level and this part of the tower may be under a negative air pressure which may reach as much as 24 in. water-gauge (125 lb./sq. ft.). At such pressures, and indeed even at pressures down to 6 in. water-gauge, it is difficult to provide any cladding to a steel framework other than concrete, which will be airtight. The natural conclusion from this is that in such cases the most suitable medium of construction is reinforced concrete. An interesting application of this is the tower over the Crown shaft at Westoe Colliery, where with a future air pressure of 18 in. water-gauge, it was found that a square concrete box section became too heavy and cumbersome and a circular tower was designed with an internal diameter of 41 ft. and a shell thickness of 10 in. (Figs. 3 and 4). The total weight of this tower together with the dead loads from the equipment installed amounts to approximately 5,000 tons.

If for other considerations a steel tower is essential, then the most satisfactory way of achieving a sound air-lock is by a steel plate casing fixed to the outside of the guide frame. This complicates banking operations because mine cars must pass through air-lock doors when they are rammed from the cage.

The possibility of using long aluminium or steel cladding sheets, with all joints made with a suitable sealing strip and jointing compound and seam bolted has been considered, but despite some favourable tests, it was decided that the joints, when subject to the normal movements of such a structure, would not remain airtight without continual maintenance.

The heavy loads to be supported over relatively large spans necessitate very deep beams and in reinforced concrete this will result in a considerable wastage of concrete in the compression zone of the beam. To obviate this, pre-stressed members have been used, notably in the two new towers at Parkside Colliery. Here the main beams are 10 ft. deep over a clear span of 63 ft. They have been pre-stressed by the B.B.R.V. system using 18 cables with a stressing force of 1,400 tons.

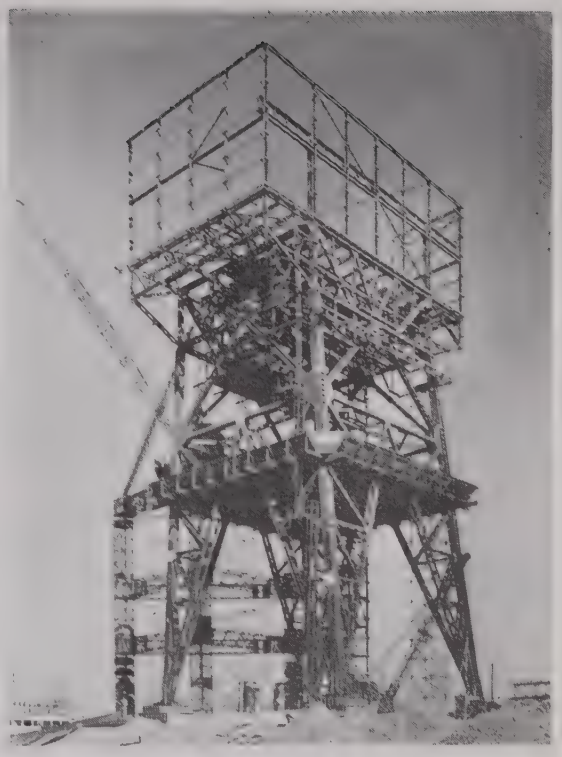

Fig. 5.—No. 2 tower Kellingley Colliery.

Structural steel towers are normally of riveted construction, but the practical problems associated with this form of construction are leading designers towards welding and the use of high strength bolts. In the No. 1 Tower now being erected at Cynheidre Colliery, extensive shop welding has been employed in the structural members which are of mild steel, material of a notch-ductile quality being used in the tension flanges of the main support girders. Site connections generally have been made with high strength friction grip bolts, but turned bolts were used to make the main connections to the steelwork supporting the winders.

At Kellingley Colliery in the Yorkshire coalfield, the steel towers were erected before the freezing operations necessary for the sinking of the shafts through water bearing strata commenced, and the foundations were designed to incorporate a jacking system to enable differential movements due to frost-heave or subsequent thawing to be counteracted. When freezing of the ground took place, the towers with their permanent winding engines were lifted about 1½ inches. Figure 5 shows No. 2 Tower at Kellingley when the steel erection was nearing completion. The lower bracing was arranged so that the pit-top buildings could be built between the tower legs.

In all towers there is a steel guide frame structure extending to bumping beam level. Its principal functions are to support equipment which positions

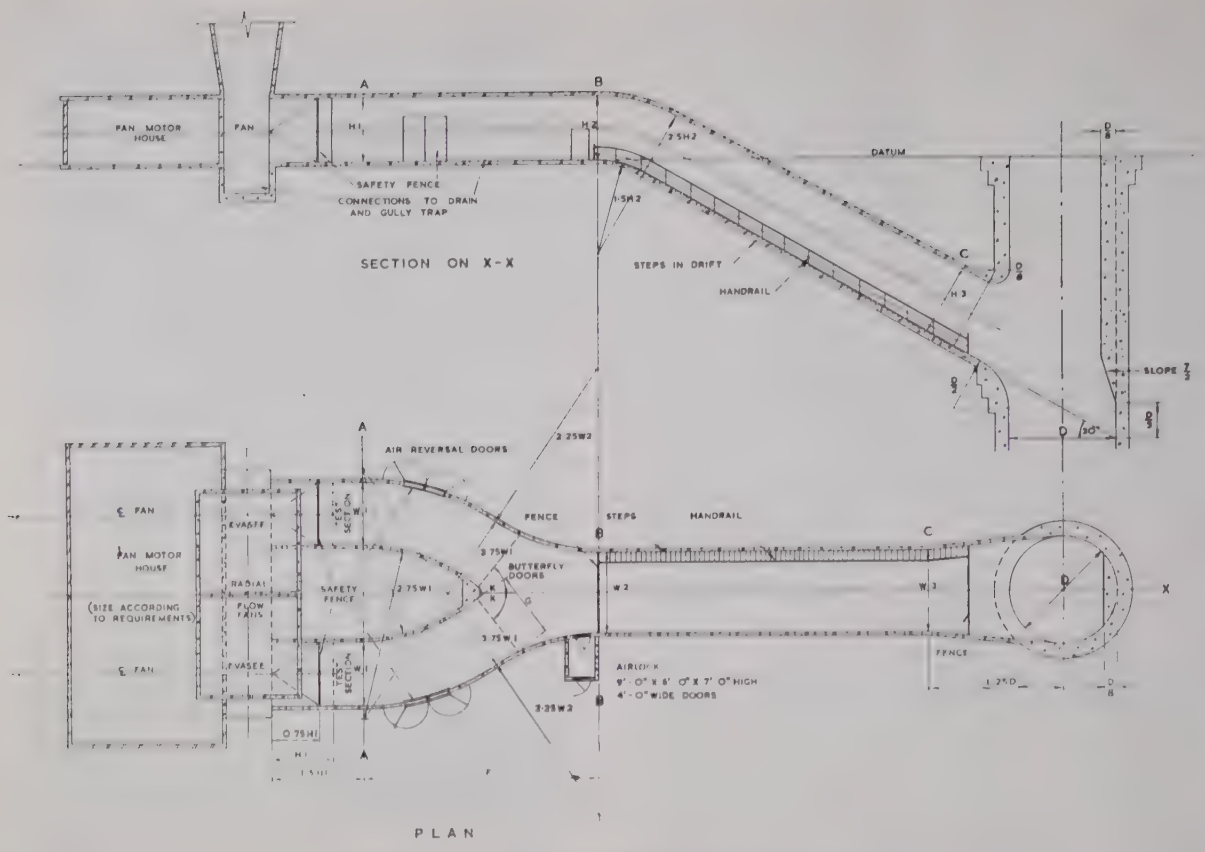

Fig. 6a. –Inclined fan drift for radial flow fans.

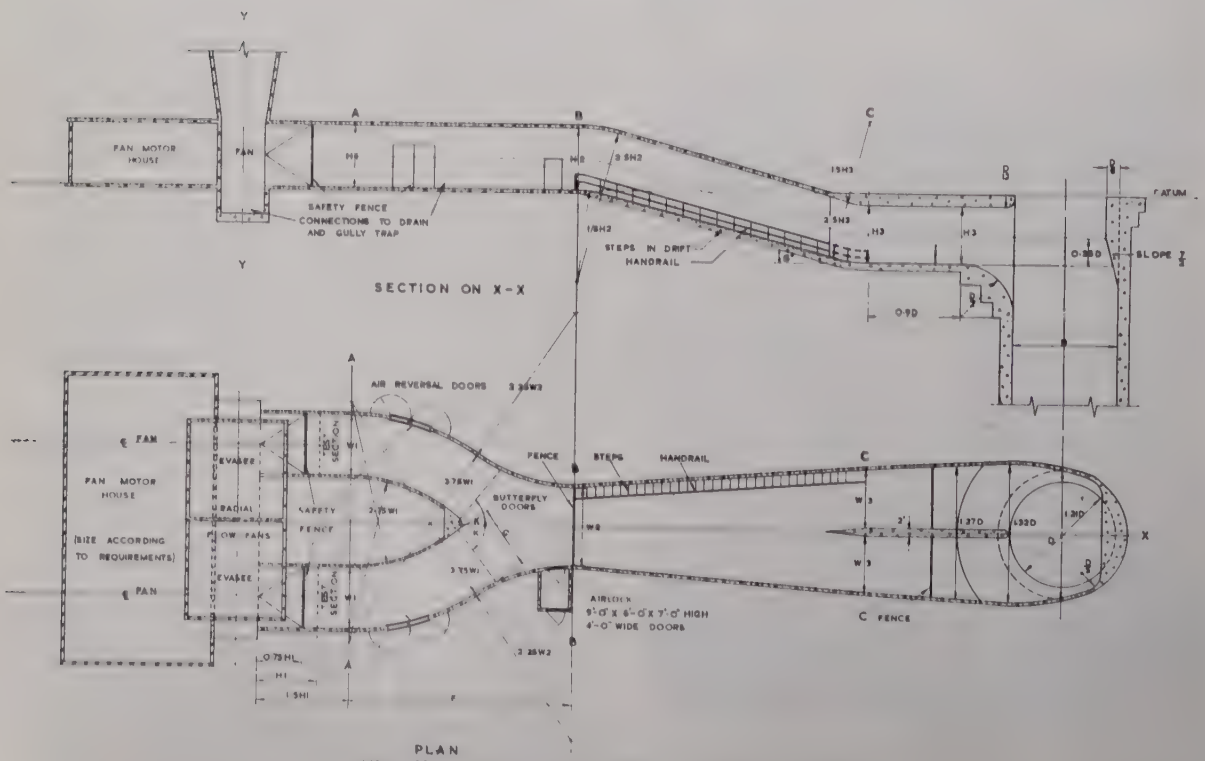

Fig. 6b.—Gallery fan drift for radial flow fans.

the cage or skip at banking level and to support arrestor and catch gear brought into operation in the event of an overwind. This structure, which under emergency conditions may be subject to very heavy loads, is usually regarded as part of the mechanical equipment of a shaft, but nevertheless it is very much within the sphere of the structural engineer.

Pit-Top Buildings

The need for greater payloads per wind led to the introduction of larger mine cars with a capacity of from 2 to 7 tons with heavier multi-deck cages. Mechanical handling methods both underground and at the pit-top underwent a considerable change. At both levels the mine car circuits are designed for automatic operation and the mine cars are pushed out of the cages by mechanical rams. After discharging coal through a tippler they are returned either by continuously rotating turntables, shunt-backs or traversers. With the handling system it is current practice to adopt consecutive decking instead of simultaneous decking of the multi-deck cages and this brings all operations under the control of one banksman for each winder.

In the case of skip winding the surface handling arrangements are simpler. The skips discharge into a receiving hopper from which the coal is fed to the conveyor belt system by apron feeders.

The buildings housing the mine car circuits are very straightforward. At the downcast shaft a single portal frame structure in either steel or reinforced concrete is usually adopted. A solid brick dado wall is essential, but above this and on the roof, asbestos cement sheeting is used. That part of the building immediately adjacent to the shaft which is required for man-walking platforms and to facilitate cage changing operations requires to be taller and may be built in load bearing brickwork or as a structural frame with panel walls.

At the upcast shaft where it may be necessary to bring the buildings within the shaft airlock, the structures become more complicated. In such cases designers may have to take account of a negative air pressure which may range from 6 in to 24 in. water-gauge. It is considered that above 6 in. water-gauge, brickwork cannot be made sufficiently airtight. Cavity brickwork with the cavity filled with dense concrete has been used at medium pressures, but where these are built as panel walls in a steel or concrete frame, great care must be exercised to ensure a sound joint between the brickwork and the frame. At the highest pressures undoubtedly the most satisfactory form of construction is reinforced concrete.

Fan Drifts

Ventilation of a pit is achieved by drawing air into the workings through the downcast shaft and out via the upcast shaft through a drift formed at or close to the top of the shaft. Fan drifts are usually of two types. The first is the inclined drift which joins the shaft about 60 feet below the surface, and the second is the gallery drift which joins the shaft just below pit bank level. Both types are illustrated in Figs. 6 (a) and (b). The former is the most common, but at reconstructed pits its plan is rarely as straightforward as that shown in the figure and the design and construction is often complicated by the presence of the foundations of an existing headframe or of adjacent buildings.

The gallery drift requires less excavation and is generally cheaper to construct. In new collieries they have certain advantages, particularly if rockhead or the water table is close to the surface. The first of this type of fan drift was built at the new Lea Hall Colliery (Lea Hall Colliery Fan Drift and Entry, Transactions of the Institution of Mining Engineers, 1955-56, Volume 115, Part 2), in the West Midlands Division.

The design of the drift and of the evasee, which is the air discharge funnel adjacent to the fan, generally presents no great problem. Because of the changes in shape of both drift and evasee, the need to avoid the inward leakage of air at vacuum pressures of up to 24 in. water-gauge and the problem of forming a junction between a rectangular drift section and a circular shaft, reinforced concrete is the only really suitable medium of construction.

Gantries and Bridges

The movement of coal on the surface of a colliery is generally by conveyor belts supported on overhead gantries, and these at a large pit can be very extensive, particularly when coal from other mines is brought in for cleaning at the preparation plant. In addition it is often necessary to provide a covered overhead walkway from the pithead baths to the man-riding shaft. Fig. 7 shows a pre-stressed concrete man-walking gantry at Lingerwood Colliery, which illustrates how long these structures may have to be. They are frequently complicated by river, road, canal or railway crossings and they provide many interesting but nevertheless reasonably straightforward problems in design. They have been designed in structural steel, reinforced and pre-stressed concrete.

Coal Preparation Plant Buildings

With the multiplicity of qualities and gradings of product now required by the industrial and domestic markets, coal preparation plants have become somewhat complex factories handling large tonnages of a very variable raw material. The buildings are large and frequently rise to a height of some 60 to 80 feet. The structure is required to support a great deal of heavy vibrating plant and as with winder towers, the proportion of live to dead load is considerable. In the author's experience some designers have not fully appreciated the magnitude and effect of these moving loads, nor have they given sufficient consideration to the relative frequencies of the plant and supporting structure with the result that alarming vibrations have occurred. In counteracting these vibrations, the monolithic nature of a concrete frame commends itself, but its advantages may well be nullified by a designer who uses his theory too well and his practical knowledge of the problems too little, and produces a design of slender beams and columns.

Coal preparation plant structures have in the past been constructed in both steel and concrete, but the present opinion in the Board is that the flexibility of steel construction to meet possible future plant changes is of over-riding importance and future plants will be built in structural steelwork though reinforced concrete may be used to first floor level. Thickener tanks and the conical washery towers are normally constructed in reinforced concrete.

Black bolted connections in steelwork subject to continuous vibration can be very unsatisfactory and to overcome this nuts with nylon locking inserts have been used.

Workshops and Stores

The National Coal Board have developed standards both for colliery and Area Central Workshops and

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Fig. 7. Pre-stressed concrete man-walking gantry at Lingerwood Colliery.

Stores buildings. Colliery workshops are either 40 feet or 50 feet clear span and 20 ft. to eaves. Generally these are precast concrete portal frame buildings, but some steel portals designed according to the plastic theory have been erected.

The Area Central workshops are 60 feet clear span and 28 ft. to eaves. They usually have two or more spans in each of which is either a 20 ton or 10 ton overhead travelling crane. They are built with steel columns supporting normal steel trusses, but some precast concrete portal frame buildings have been erected. The choice has been based on either cost or local preference. In the former case there has generally been little to choose between the two forms of construction.

Pithead Baths

These are invariably two storey buildings and professional opinion is about equally divided as to whether they should be of load bearing brickwork or of framed construction. Bearing in mind that the locker rooms may require a clear span of 30 feet, the author favours a framed construction with a pre-stressed plank floor and roof to give a clear soffit for the passage of heating ducts to the lockers. In the building at Chislet Colliery and illustrated in Fig. 8 the frame is of precast concrete with some in situ 'make-up' concrete, with 10 in. prestessed planks in the first floor and the roof.

Fig. 8.—Pre-cast concrete frame, pithead baths—Chislet Colliery.

Ancillary Buildings

There are a number of other buildings usually associated with the operation of a colliery, some of which may sometimes be incorporated in the pit-top building. These are principally to accommodate transformers and switchgear, air compressors or motor generators. A number of power stations capable of generating about 5 megawatts are being built to burn unsaleable slurry from the coal preparation plant. These buildings are steel framed and the slurry is handled by a grab working off a telpher structure.

Coal Processing Plant

In addition to the mining and preparation of raw coal for the market, is the task of processing of coal to produce coke, smokeless fuels and a large variety of chemical by-products. This adds another long list of structures to the work of the structural engineer. They present no unusual problems other than those which normally confront any designer working in the chemical industry.

Fig. 1, which shows Cwm Colliery coal preparation plant and coking works, illustrates very well the many different buildings and structures to which reference has been made in this paper. On the extreme right of the picture are the two steel headframes. In front is the coal preparation plant building and the coal blending bunkers are in the centre of the picture. The coke ovens are on the extreme left. This picture admirably illustrates the part played by the overhead conveyor gantries in the operation of a colliery.

Underground Works

There is a tremendous amount of constructional work carried out below ground involving the traditional materials of the structural engineer, steel and concrete. The basis of design of such construction has been largely empirical because the forces involved cannot readily be calculated or otherwise determined.

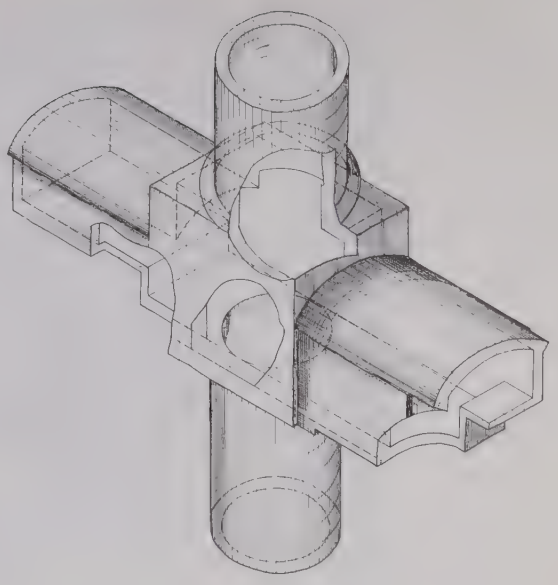
Present-day legislation requires that such work is controlled by a mining engineer, but there is no doubt that the structural engineer can make a very vital contribution in the application of modern design and construction techniques.

Before discussing underground work, it is necessary to refer to what is termed the 'shaft pillar.' This pillar is a zone surrounding the two shafts from which no coal is removed so that there is no undermining of the permanent support of the shafts and the pithead structures. All constructional work within this zone must be so designed and built that there is no significant disturbance of the strata. On the surface the area of the shaft pillar is that which will encompass all surface buildings and structures and the zone extends downwards from the perimeter of this area at an angle between 30° and 45° to the vertical until the deepest coal seam is reached. Broadly speaking constructions within the shaft pillar are regarded as permanent as distinct from those outside the pillar which are subject to movement due to mining operations.

Shafts and Insets

The sinking and lining of the shafts themselves present constructional rather than design problems and these have been outlined in a paper by Young, Longden and Metcalf, 'Development in the Coal Mining Industry,' *Proceedings of the Institution of Civil Engineers*, Volume 6, April, 1957.

In present-day sinkings in this country concrete is normally used instead of brickwork or cast-iron segments for lining the shaft. Where the sinking is through non-water bearing strata, the concrete is no more than a lining and the thickness is determined empirically. Reinforcement is only used when any strata movement is considered likely.



Isometric view of inset.

Fig. 9.

The determination of the thickness of a concrete lining to withstand the high water pressures which might be encountered in a deep shaft sunk through the water measures should take account of both strength and stability. It has been common practice to use the Lamé formula for the design of thick shells which is based on the elastic theory. It is suggested that consideration should be given to the utilisation of the plastic properties of concrete to give a uniform stress distribution across the section and make maximum use of the material. The Lamé theory assumes a uniform pressure around the shaft, but this may not always be the case because of the non-homogeneous nature of the surrounding strata. It may be useful to check the stability of the lining by applying the formula for buckling of thin cylinders subject to external load as attributed to Professor Southwell (Strength of Materials (Page 101), John Case). When interpreting this it must be realised that the rock will generally provide a restraining factor, but the stability may be disturbed by local variations in strata.

It is interesting to note that in 1907, in a paper on the design of cast iron tubbing, Professor Morrow (*Transactions of the Institution of Mining Engineers* Volume 34, Part I, 1907-1908), applied this buckling theory and used a formula which he attributed to Professor Bryan, which, when reduced to the same terms is identical to that by Southwell.

The following table compares wall thicknesses derived from the above three methods based on a hydrostatic pressure of 500 lb/sq. in. with varying degrees of concrete.

Internal Diameter of Shaft
Loading. 500 lb/sq. inch

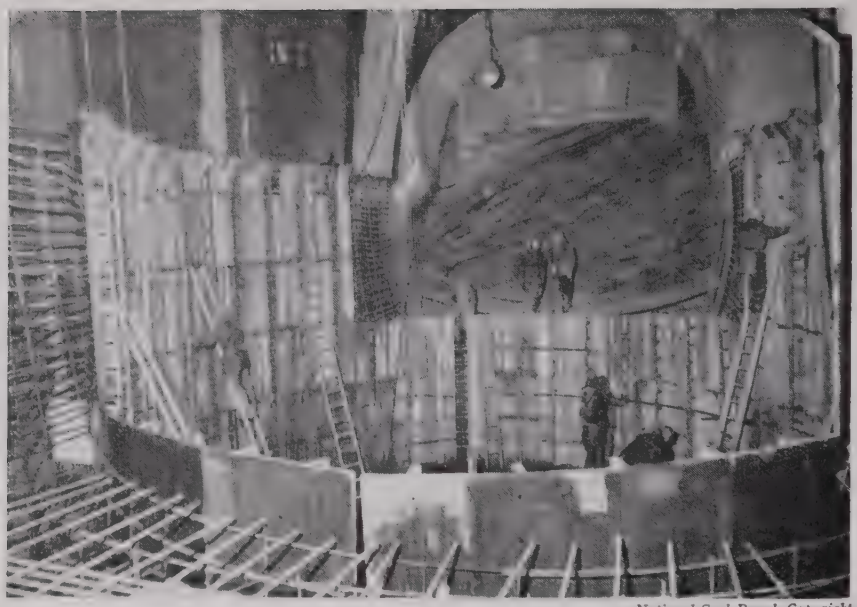


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Fig. 10. Cynheidre Colliery, showing 1,450 ft. inset shuttering and reinforcement in No. 1 shaft.

$$\text{Allowable concrete stress} = \frac{\textit{Cube Strength}}{3}$$

Concrete Cube Strength		
4,000 lb/sq. in.	5,000 lb/sq. in.	6,000 lb/sq. in.
Poisson's Ratio		
0·15	0·15	0·15
Modulus of Elasticity—'E' (assumed)		
$3{\cdot}0 \times 10^6$ lb/sq. in.	$4{\cdot}0 \times 10^6$ lb/sq. in.	$5{\cdot}0 \times 10^6$ lb/sq. in.
Plastic Design		
86·5 in.	61·8 in.	48·0 in.
Lamé Theory		
143 in.	83·5 in.	59·0 in.
Buckling Theory—(Southwell)		
12·5 in.	11·4 in.	10·5 in.

The design of a shaft inset is a matter of much greater complexity, particularly when it is accompanied by an increase in the diameter of the shaft to avoid impedance of ventilating air when a cage is at the inset. Included in the term 'inset' are all the works up to 60 feet on either side of the shaft. Fig. 9 shows a typical inset, in this case without any widening of the shaft other than that due to the box construction which would otherwise occur at the junction of the curved shaft walls and inset roof.

At Cynheidre Colliery the insets required structures 36 feet internal diameter and 72 feet high, pierced by the side openings from the roadways at a depth up to 2,500 feet below the surface. The design was based on the Dutch practice wherein the rock contained in an ellipse based upon the slip planes down to the base of the drivage is considered to be supported and the hydrostatic pressure of the rock is not considered to be acting. To accommodate the forces arising very stiff arch portals were constructed and the forces against the side walls were carried back into these portals by diagonal arches. The reinforcement was so arranged that panels of bars could be fabricated and welded on the surface and hung from the previously concreted sections of the inset in order to enable the construction to proceed downwards. The construction of a typical inset at this colliery is shown in Fig. 10.

Skip Pockets

Where coal is wound in skips, pockets are formed at pit bottom and sometimes intermediately in the shaft to house steel bunkers into which coal is tipped either by conveyor or mine car, pending its discharge into the shaft skips. Fig. 11 is a drawing of one of three such skip pockets to be constructed in the new shaft at Westoe Colliery. In designing these it was decided to adopt a circumferential load of 1,120 lb/sq.ft. with an additional 1·120 lb/sq. ft. acting at an angle of 45° to the horizontal on one half of the roof arch of the pocket. To reduce the number of steel bars to a minimum, the design was based on a work-hardened steel. The disposition of the reinforcement was arranged to suit the actual shuttering and concreting programme which the contractor intends to use.

The basic design involves a series of rectangular frames. Cross beams required to carry the skip-weighing equipment (the load per beam being about 50 tons), were designed to act also as struts, thus reducing the long spans of the side walls of the pocket. The detailing of these members was complicated by the fact that they had to be outside the line of the shaft wall and they also required slots for the skip weighing machinery.

The excavation for the skip pocket will be carried out in two stages :—

1. Thirty feet diameter approximately by 62 feet deep.
2. Starting from the bottom of this 62 foot section, headings will be driven back for the side walls in depths to suit the 'steps' in the skip pocket walls.

In underground work of this nature it is essential that the design shall be closely related to construction methods.

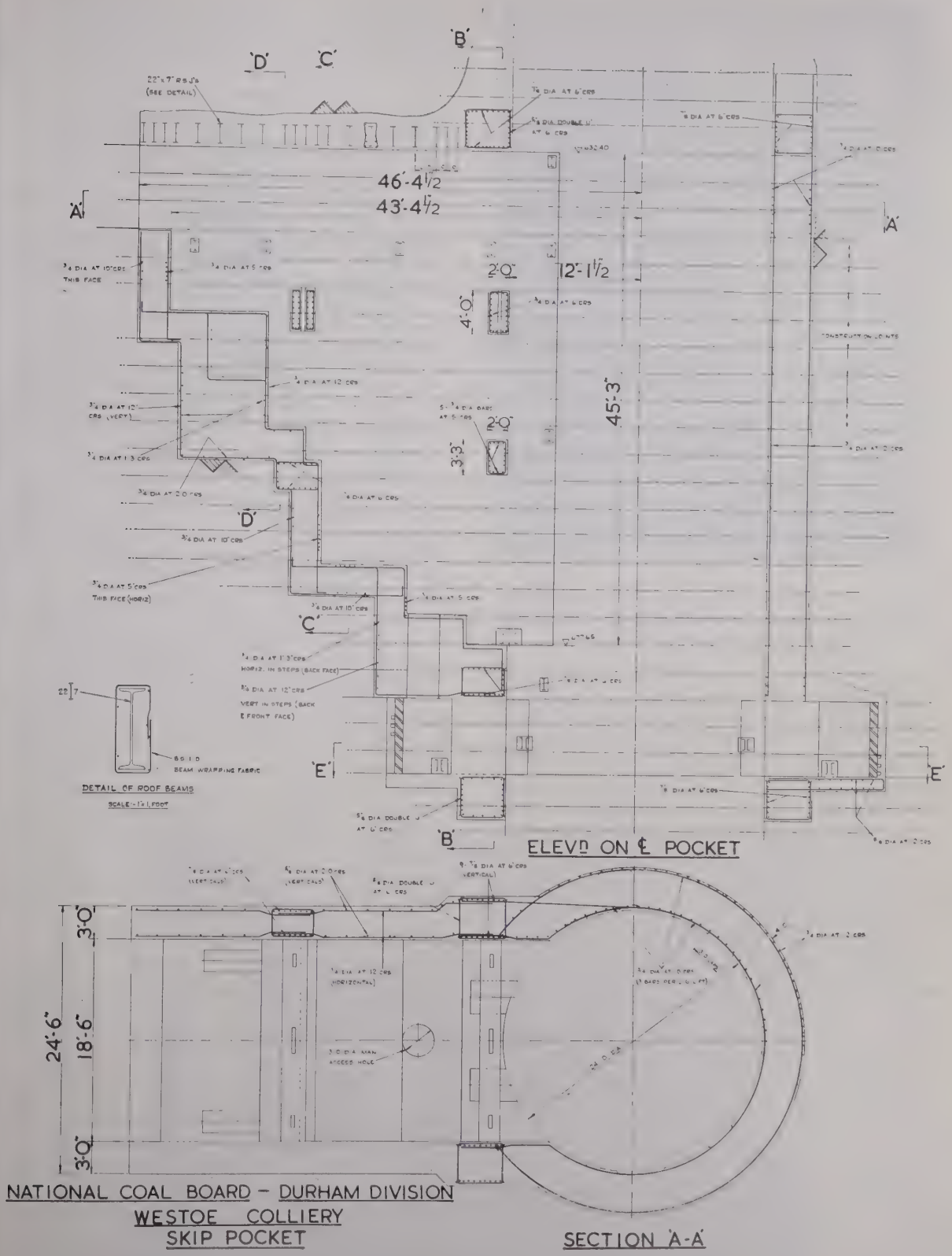
NATIONAL COAL BOARD – DURHAM DIVISION
WESTOE COLLIERY
SKIP POCKET
ELEVn ON ℄ POCKET
SECTION 'A-A'
DETAIL OF ROOF BEAMS
46'-4½
43'-4½
12'-1½
45'-3"
24'-6"
18'-6"
3'0"
3'0"

Fig. 11.

Fig. 12.—Skip pocket construction at Cotgrave—looking upward from shaft bottom showing west side wall completed.

Fig. 12 shows a skip pocket under construction at Colgrave Colliery. The brickwork was used as shuttering.

An interesting point in the construction of shafts and insets is the method that has been developed of delivering the mixed concrete down the shaft through a 5 in. or 6 in. diameter steel pipe. At depths greater than 300 feet at which segregation of the mix occurred owing to its high speed in the pipe, a header was employed. This consisted of a stop end fitted at the bottom of the vertical pipe with a branch pipe 12 in. above the stop end and inclined at an angle of about 18° to the vertical. To this branch pipe a flexible hose was fitted. With this arrangement even at a depth of 3,000 feet, the concrete showed no signs of segregation and issued from the end of the delivery hose at a low velocity.

Reference has been made to Dutch practice in the design of underground structures and while it is not within the scope of this paper to elaborate on the theory, some further explanation of it might be of value. It is based on an assumption that a tensionless body is formed over a tunnel section. This tensionless body is limited by two shear planes starting at the foot of the walls and the pressure ellipse whose horizontal axis is formed by the line drawn at the level of the top of the arch. The height of the pressure ellipse is related to the height and width of the tunnel section and tabular values have been computed Fig. 13 (a) is a diagram of the 'tensionless' body and Fig. 13 (b) shows its application to a tunnel where loading is assumed to be unsymmetrical and the pressure ellipse is in an unsymmetrical position over the tunnel. From this loading diagram bending moments can be derived from which concrete thicknesses and reinforcing bar sizes can be determined.

Obviously the calculations are based upon assumptions, but the theory behind these assumptions deserves a critical examination and correlation with practical experience and observation in this country.

Underground Roadways

From a support point of view underground roadways can be divided into three categories :

(i) Main roads in settled ground and within the shaft pillar (e.g. pit bottoms).

(ii) Main roads subject to movement which must be controlled at any cost.

(iii) Subsidiary roads which are generally located in ground which is subject to movement because of mining operations and where maintenance is related to their required life.

Category 1.—*Main Roads*

In new and reconstructed mines these roads are now generally supported by reinforced concrete side walls and elliptical arches. The section is usually 16 ft. wide by 12 ft. to the soffit of the arch, but in special circumstances a 22 ft. by 14 ft. section may be needed.

At oblique intersections of two roadways the arch span will be increased very considerably and the roof formation becomes complicated. Fig. 14 shows a typical pit bottom roadway and intersection. With the absence of reliable design data inherent in underground work concrete thicknesses have generally been based upon past experience of similar work.

Category 2. *Main Roads with Controlled Movement*

These roads are generally supported by heavy steel arches strutted and lagged. The arch members are usually 6 in. × 5 in. rolled steel section for roads of 16 ft. width and are placed at about 3 ft. centres. Universal beam sections are now coming into use. Another trend is to incorporate greater yielding ability in the supports by fixing stilts or using specially designed arches, the object being to absorb movement whilst retaining the shape of the roadway. Concrete block linings have been used and timber crush pads are built into the courses of blockwork to provide the required yield. At one new colliery at least roadways have been lined with concrete placed by a compressed-air gun process using a 1 in. aggregate. The results so far have been satisfactory and appear to offer a promising field for development. An advantage of a smooth concrete lining is the reduced resistance to air flow which is of very marked value to the ventilating engineer.

Timber or wire mesh lagging is usually placed behind the arches. Recently experiments have been carried out on the use of reinforced concrete laggings having both pre-stressed wires and normal mild steel reinforcement. The concrete section adopted was 5 in. by 2 in. and the test carried out included a central point load to failure from bending and also loading adjacent to the supports to ascertain the effect at failure of the bond. The tests revealed that generally speaking the mild steel reinforcement is to be preferred to the pre-stressed type as the latter was subject to an abrupt fracture, whereas with the mild steel reinforcement the approach to yield point was clearly visible. This fact is of the greatest importance when the roadway laggings are inspected to detect impending failure. In addition it was found that the section could fail due to inadequate bond with high tensile steel, but this did not occur with the M.S. reinforcement.

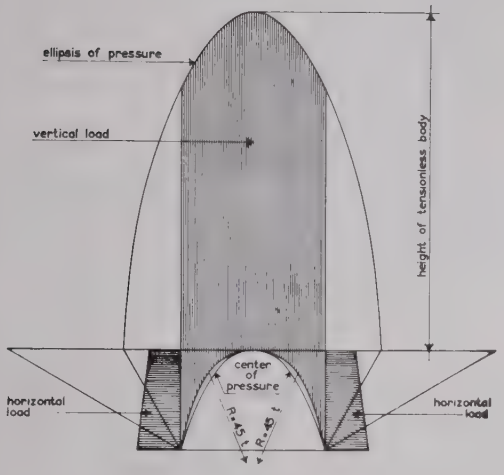

Fig. 13a.—Tensionless Body

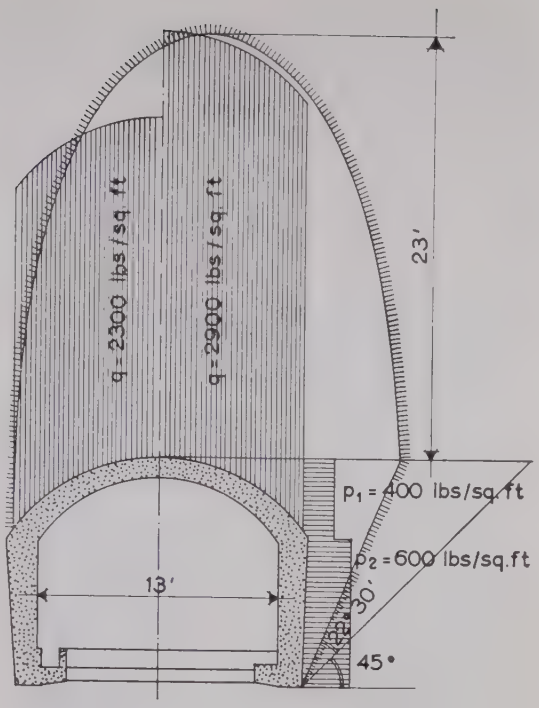

Fig. 13b.

Fig. 14.—Typical pit bottom roadway and intersection.

Category 3.—*Roads Liable to Movement*

Where coal has been extracted, the roof and floor must converge, however good the packing. Therefore, the supports for roads in moving ground must be designed to incorporate enough yield to allow for this convergence. Otherwise the arches will be distorted or pushed into the floor, when the yield provided by the lagging and loose packing is exhausted. This occurs usually within 10 to 20 yards of the face.

The distortion can be prevented by taking systematic back rips, though with good stilts or yielding arches such back rips can be reduced in number and size.

Much still has to be learnt about the amount of yield an arch should incorporate, the pressure under which it should yield, and the lagging with which it should be lined.

The principle of lagging and strutting is not only to prevent weathered rock falling through, but also to tie the supports into a whole and so spread the load uniformly over the whole system. Experience has shown that whilst struts should be as rigid as possible, lagging should provide a certain amount of yield, with the exception of work in settled ground. It follows then that corrugated sheets and particularly cheap wire mesh are preferable to timber, and much preferable to rigid concrete slabs.

In many underground roads the roof strata forms a beam over the roadway. It is then better practice to leave the roof intact, supporting it on a flat arch (Beam) set on yielding props, and if necessary provide additional strengthening with roof or strata bolts.

Strata bolts are a comparatively recent innovation, and have been used in this country increasingly during the past five years.

The principle of strata bolting is the forming of a composite arch or beam of great combined strength. The use of strata bolts will of course be determined by the nature of the strata, and for this purpose test bolts are driven and pull tested. They can be used in conjunction with traditional arches or on their own, they also frequently fulfil a secondary function of supporting lagging.

Pre-stressed precast arches have been tried in Scotland. It was found that these concrete sections were heavy, easily damaged and possessed insufficient yielding properties. The general opinion therefore is that the application of concrete to arch construction has a limited future.

Acknowledgement

The author would like to record his thanks to the National Coal Board for permission to present this paper. He would like also to acknowledge his debt to his colleagues in the Board and to the many Consulting Engineers who have provided so much of the material for it.

The opinions expressed in this paper are entirely those of the author and not necessarily those of the National Coal Board.

Book Reviews

Plastic Analysis of Structures, by Phillip G. Hodge, Jn., Ph.D. (New York and London : McGraw-Hill, 1959.) 9 in. × 6 in., 353 + xiv. pp., 81s. 6d.

The first part of this book deals with beams and framed structures. The theorems and methods of plastic analysis are proved and discussed and illustrated by examples of their applications to building frames open-framed girders, non-rectangular frames and grids. Deflections and the effects of variable repeated loadings and axial forces in frame members are discussed. There is one chapter dealing with design of structures, as distinct from analysis.

The second part deals with the analysis of structures subject to combined stress. It is demonstrated that the statical and kinematic theorems are generally applicable to cases of combined stress when the yield condition is stated and the application of these theorems in the analysis of beams when the effect of shear is taken into account, beams and grids under bending and torsion, slabs, cylindrical and spherical shells, plane-stress problems, and impact loading, is given.

The mathematics of the second part is not easy. The last chapter of the first part, dealing with lineal members under combined bending and direct stress, introduces the graphical representations of the relations between the components of stress which produces yielding. This is used throughout the second part and the conceptions of generalised stresses and the corresponding generalised strains, also deformation rates and dissipation functions, are introduced.

All the author's remarks are couched in algebraic form and the notation is complicated and unusual, German letters being freely used. Many references are listed, including references to some problems whose treatment has been partially or wholly omitted from the book, owing to lack of space. Many exercises and problems are given at the end of each chapter ; these are nearly all of a general analytical type.

This is an excellent textbook, but the second part particularly is of chiefly theoretical interest and is far from practical design office work. L.G.

The Mechanics of Engineering Soils, by P. L. Capper and W. Fisher Cassie, 3rd Edition. (London : E. & F. N. Spon, 1960). 9 in. × 5½ in., 315 + xvi, pp., 30s.

The aim of this book is to give an introduction to the science of soil mechanics to young engineers and architects, setting out the fundamental laws and theories and the present state of the subject. The text of the third edition has been revised in accordance with recent developments, tables and diagrams have been amended wherever necessary, and a number of new diagrams has been added. Some sections, such as those dealing with equilibrium moisture content, stability of slopes and road design, have been re-written and extended.

Recent Engineering Work at the Building Research Station *

Structural research at the Building Research Station is aimed partly at extending the general body of structural theory and partly at codifying this general body of theory into Codes of Practice and similar Standards. Some programmes are undertaken specifically to help in the redrafting of a particular Code. A recent example has been a series of tests[1] designed to check one of the revisions in the latest issue of B.S.449, 'The use of Structural Steel in Building.' This relates to the load-carrying capacity of concrete-encased steel stanchions subjected to axial and eccentric loading. In the 1948 edition of the Standard, the only structural benefit the designer could derive from such encasement was a reduction in the assumed slenderness ratio of the stanchion due to the stiffening effect of the concrete. It has been shown that such stanchions can in fact be safely treated as composite sections in which a proportion of the direct load is carried by the concrete, acting at a stress of one-thirtieth of that in the steel. In the latest version of the Standard, design on this basis is allowed with the proviso that the working load shall not exceed twice that of the corresponding bare steel stanchion. This can result in savings of up to 30 per cent in the weight of steel section required.

Recent work on reinforced concrete has been concentrated on lightweight aggregates and on shear. An increase in the production of reliable lightweight aggregates in this country has prompted an extensive investigation into their use in reinforced concrete. The first results of this work have now been summarized[2]. They do not yet permit an exact prediction of the degree of protection against corrosion afforded by lightweight concretes, but they do suggest that corrosion is influenced more by the thickness of the cover provided and the quality of the concrete than by the nature of the aggregate. Comparative tests, using normal and lightweight aggregates, on reinforced concrete beams designed to fail by a breakdown of the bond between the concrete and round mild-steel bars, show that the bond strength developed by lightweight concretes is less than that developed by a dense concrete of the same crushing strength. The bond stresses permitted by CP.114 should therefore be reduced.

The influence of shear on the strength of normal reinforced concrete beams is much more complex than present Codes of Practice imply. There are so many interacting variables that a comprehensive and practical method of design for shear is not easily arrived at and the relevant recommendations of the current Code do not appear to be adequate. A contribution[3] to the discussion on a recent American paper, includes a summary of work at the Building Research Station on shear strength under repeated loading. For practical purposes a beam may be considered to have failed in shear when a main diagonal crack has developed, although the load at which this occurs may be less than the maximum load which the beam could sustain. Using this criterion of failure, if a pulsating load is superimposed upon a static load representing the design dead load, the highest value which can be applied for one million cycles without such cracking is only about 70 per cent of that sustained in static tests. Another note describes a static loading test on a specially prepared beam in which a thin former was used during casting to produce two smooth-sided cracks similar in extent and position to the flexural cracks observed in other beams just before the onset of the main diagonal crack. The low failing load compared with that of a normal beam suggests that the forces developed by the interlocking of the aggregate along flexural cracks

Fig. 1.—A test on an eccentrically-loaded encased steel column. Other specimens are seen on the right.

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* *Abstract from the third periodical review of engineering work at the Building Research Station. Abstracts from previous reviews have appeared in "The Structural Engineer," Vol. XXXVI, No. 5, p. 180 (May, 1958), and Vol. XXXVII, No. 3, p. 87 March, 1959).*

Fig. 2.—Tests to compare the long-term outdoor behaviour of similar reinforced concrete beams cast with different aggregates, three lightweight and one normal. Each of the nearer beams has been loaded initially until it cracked and then kept under load.

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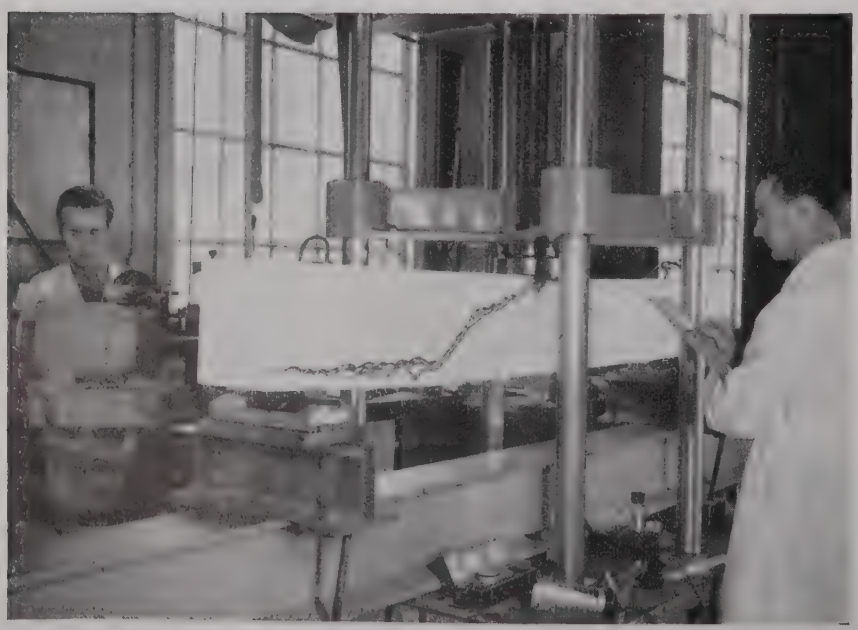

Fig. 3.—A shear failure, under static load, of a simply-supported reinforced concrete beam.

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play an important part in determining the load at which the diagonal crack that will ultimately cause failure is likely to appear.

Wind loading on buildings can present many different problems. A recently issued Digest[4] explains how the result of meteorological observations have been interpreted in the design recommendations given in C.P.3, Chapter V. This Digest also discusses the results of recent wind-tunnel tests on models of rectangular buildings with mono-pitched roofs with little slope, which show that with this form of construction the most severe conditions are likely to occur when the wind blows obliquely to the faces of the building. A more reliable method of estimating the wind forces on flat and shallow pitched roofs is proposed, to be used in conjunction with a load factor of three against uplift and overturning.

One paper[5] comes from the Soil Mechanics Division of the Station. It gives details of the mechanical and physical properties of London Clay at depths between 50 feet and 160 feet. These have been determined from samples taken at the working face during tunnelling operations at a number of sites, and also by a study of the appearance of the working faces as mining proceeded. The importance of this type of investigation to supplement the findings of borehole exploration is twofold. Firstly, visual observation at the tunnel face can throw light on structural characteristics of the formation that are not revealed by normal boring methods. Secondly, the opportunity can be taken to obtain relatively large samples for laboratory tests with the minimum risk of disturbance. Tests on specimens prepared in this way expose some shortcomings of the use of bored samples for the determination of physical characteristics, and indicate that the clay is stronger and less compressible than these samples suggest.

A new series of papers under the general title 'Factory Building Studies' will deal with many aspects of design. In the first[6], the particular case of the multi-storey factory is discussed, and the wide range of considerations than can influence both its main conception and the finer points of detail is outlined. Multi-storey construction may sometimes offer immediate economic advantages in terms of factory organisation and initial cost, but its long-term efficiency depends largely upon the extent to which changes in functional requirements can be predicted and accommodated. An adequate appraisal of the effects of possible changes in manufacturing techniques is therefore a pre-requisite of a satisfactory design.

The fourth study of this series[7] deals with design loads. Self-weights of the structure and its cladding should be simple to estimate, but this is not true of the superimposed loading. This loading may arise from so many different sources, temporary or permanent, that it is difficult to assess it with the accuracy that is desirable for economic design. To assist in this assessment, data have been compiled on the loads imposed by many types of machine, ancillary plant, service equipment and fittings. The importance of anticipating future requirements, rather than designing solely for the present, is again stressed.

The use of mechanical equipment on the building site is growing rapidly. Most noticeable are the cranes, now available in a wide range that is described in another Digest[8]. Other papers dealing with equipment look more closely at one type of crane—a Continental climbing crane designed for use on buildings of eight or more storeys[9]—and describe smaller pieces of equipment developed at the Building Research Station for use in the lifting and placing of concrete and mortar[10,11] and in the loading of packed bricks on to a lorry[12,13].

General questions of administration, site organisation and cost control are considered in three papers. One is particularly concerned with cost control[14] and the others with the increasing dependence of productivity on efficient site organisation and office administration[15,16] as more mechanical plant is introduced. The latter present the results of an extensive survey of the existing operational structures of the industry both in this country and on the Continent.

In reducing costs, continued attention to details is also necessary. Recent surveys[17] show that, although cement may be saved by using properly designed concrete mixes, since such mixes are leaner and drier, the saving will probably be more than offset by the extra time and labour spent in supervising, placing and compacting. Overall economy is more likely to be achieved by the use of a concrete with a slump between 2 in and 4 in. where vibration is used, or between 3 in. and 6 in. where hand compacted, with low-slump concrete used only where necessary to ensure a high durability.

References

1. Stevens, R. F., "Encased steel stanchions and BS449," *Engineering*, 1959, 188 (4879), 23rd October.
2. Short, A., "The use of lightweight concrete for reinforced concrete construction," *Reinforced Concrete Review*, 1959, Vol. (3).
3. Taylor, R., "Fatigue behaviour of reinforced concrete beams"—Contribution to discussion of a paper by Tien S. Chang and Clyde E. Kesler, *American Concrete Institute Journal*, 1959, 30 (9), March.
4. Building Research Station, "Wind effects on roofs," *Digest, No.* 122.
5. Ward, W. H., Samuels, S. G. and Butler, M.E., "Further studies of the properties of London Clay," *Géotechnique*, 1959, 9 (2), June.
6. Allen, W. A., "Modern multi-storey factories." A discussion of their design, *Factory Building Studies No.* 1, London, 1959, H.M.S.O.
7. Apcar, H. V., "Structural loading in factories," *Factory Building Studies No.* 4, London, 1959, H.M.S.O.
8. Building Research Station, "Cranes for Building," *Digest No.* 129.
9. Vallings, H. G., "Trials with a climbing crane," *Contract Journal*, 1959, 19th February.
10. Vallings, H. G., "A concrete skip with a rubber body," *Contract Journal*, 1959, 5th March.
11. Vallings, H. G., "Direct placing of ready mixed concrete," *Contract Journal*, 1959 (4176), 9th July.
12. Vallings, H. G., "Loading packed bricks for transport," *Claycraft*, 1959, 3.
13. Vallings, H. G., "A conveyor ramp for lifting loads carried on hand barrows or trucks," *Mechanical Handling*, 1959, October.
14. Reiners, W. J., "Research, cost planning and cost control," *National Builder*, 1959, 38 (9), April.
15. Sansom, R. C., "The organisation of building work," *The Builder*, 1959, 197 (6077-6083).
16. Sansom, R. C., "Organisation of building sites," *National Building Studies Special Report, No.* 29, London, 1959, H.M.S.O.
17. Forbes, W. S., "Production aspects of mix design of concrete in building work," *Contract Journal*, 1958, 13th November.

Brinsworth Steel Strip Mill *

Discussion on the Paper by Donovan H. Lee, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mech.E. (Member of Council), G. O. Kee, B.Sc.(Eng.), A.M.I.C.E., and N. Lancaster.

The Chairman introduced the authors who then presented the paper, and showed a large number of slides, which illustrated the structural aspects of the Brinsworth strip mill. They also showed a very interesting film of the sequence of operations in the production of steel strip; starting with the charging and tapping of the molten metal into the ladles, the control of analysis and temperature, cooling and annealing processes, the rolling of the ingots by stages down to strip, the eventual emergence of the strip and the coiling of it at a rate of about 30 m.p.h.

There were also pictures of the forging of railway wheels and axles and other components, and the subsequent heat treatment.

Discussion

The Chairman, proposing a hearty vote of thanks to the authors for their most excellent and interesting paper and their wonderful film, recalled having served his apprenticeship at a similar works, and commented that when watching the film he could really 'smell' steel.

Mr. V. Watkins (International Construction Co., formerly Chief Engineer of Messrs. Steel Peech and Tozer), was invited to address the meeting, and said it was a signal honour and privilege to do so on behalf of Messrs. Steel Peech and Tozer.

Speaking first of the film that had been shown, entitled 'Steel Rhythm,' he said it was taken of the main works of Messrs. Steel Peech and Tozer shortly before the strip mill came into production. It gave some idea of the magnitude of operations in such a plant.

All that had been illustrated to the meeting had been achieved by evolution. Such things did not happen in a day, a week, a year or even a generation; the Brinsworth steel strip mill was the result of about 300 years' research into methods of producing steel strip, which term also covered continuous steel sheet. Our forefathers, he said, were at one time able to manufacture single sheets, 4 or 5 ft. long, by the old conventional Staffordshire hand mills. The Brinsworth mill provided an outstanding example of the continuous production of steel strip, which was used extensively in everyday life nowadays, for making domestic utensils, motor car bodies and a host of other things, including steel tubes; every component part of a bicycle except the ball bearings was made from strip.

Dealing with the history of the development of rolling mill practice, he said the early rolling of flat metal was restricted to metals of sufficient ductility to permit of cold work, such as gold and lead. The earliest mill for this purpose of which we had any record was illustrated in a sketch by Leonardo da Vinci, in about 1495. A hand mill for rolling lead was constructed in 1615, and records 100 years later showed mills for rolling lead and copper, usually powered by horses or water wheels.

The early working of iron was generally accomplished under a hammer. Thin plates of iron were coated with tin prior to 1665.

The beginnings of the rolling of iron were rather hazy, but it was definitely known that the manufacture of tinplate was effected in South Wales by the rolling process as early as 1728, the site of operations being at Pontypool, Monmouthshire. It was believed that a man named John Hanbury was responsible for this development.

The steam engine gave added impetus to iron manufacture which, with the accessibility of iron ore and coal, brought about a rapid expansion of the industry. In fact, for many years almost all the tinplate produced was made in Wales, where the art was developed and held in great secrecy.

For a long period the methods of tinplate and sheet manufacture remained substantially unchanged, there being only a gradual increase of roll diameter and length, accompanying a strengthening of the mill roll housing.

Strip rolling, however, progressed through a period of steady development, beginning with the old hand mill about 1875 and evolving to the straight continuous mill in 1923. During that period the maximum strip widths rolled gradually increased from 5 in. to about 24 in. It was only natural, too, that efforts were made to apply continuous methods to the rolling of steel sheet.

The modern continuous rolling mill process, however, was really an American development. The Germans had a go at it many times, and in 1892 they built a mill for the rolling of sheets in multiple lengths in Teplitz, Germany. This mill produced sheets in widths up to 50 in., gauges of 0·078 and heavier, and lengths up to 60 ft.; but great difficulty was experienced owing to the non-uniformity of gauge. A lot of money was spent on the mill; but as the result of technical difficulties and the absence of the 'know how' it was abandoned in 1907, and the owners reverted to the methods previously used.

In November, 1902, the American Tinplate Company installed in their Monongahela works, near Pittsburg, a mill designed by C. W. Bray, another attempt to develop the continuous process. But a decreased percentage of primes, high scrap loss and roll breakage prevented the economic operation of the mill, and it was abandoned in 1905.

The experience gained on that mill, however, led to the belief that better results might be obtained with heavier sheet gauges, and in 1905 the Company built a somewhat similar mill at their Mercer works. The mill was shut down and dismantled in 1910 after only five years of spasmodic operation.

The next development came about 13 years later, when the American Rolling Mill Company built a mill invented by John B. Tytus after ten years of experimentation. It was located at the Company's Ashland plant and it demonstrated the practicability on a

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commercial basis of hot rolling wide, thin, flat material in multiple lengths by the continuous process.

The continuous mill stage was thus reached; strip was rolled and cut off in pre-determined lengths, whereas the old method used was very much like a domestic mangle, the material in short single pieces being pushed through the middle of the rolls and pulled back over the top.

In 1916 A. J. Townsend and H. M. Nangle designed and built a mill at the works of the National Pressed Steel Company, Massilon, Ohio, to roll strip from 6 in. to 24 in. wide and in thicknesses down to No. 16 gauge or heavier. This mill formed part of the Massilon unit of the Republic Steel Corporation. The experience gained from it proved to Townsend and Nangle the feasibility and possibilities of the further application of strip rolling practice to sheet widths.

In 1926, these men built a mill of their own design in the plant of the Columbia Steel Company at Butler, Pennsylvania. It was the prototype of the present day continuous medium and wide strip mills, of which, he believed, the Brinsworth mill was one of the most modern and up-to-date examples.

Two developments were of major importance in the evolution of the modern precision back up and work roll strip mill. The four high mill, with bearings, supplied the mill rigidity which was so necessary for the successful rolling of wider material to lighter gauges within acceptable tolerances. The bearings had to be made to a very high degree of accuracy, because any fault would be reflected on the strip surface. Simultaneously with this development the use of the Ward-Leonard control system had provided a flexibility of speed adjustment which had made possible the proper correlation of mill drafts in the successive stands.

THE CHAIRMAN invited the speaker to say a little about scale, and what was done with it.

MR. WATKINS said the amount of scale per ton of steel rolled varied greatly, and that it varied in thickness. When the metal left the furnace the scale might be $\frac{1}{16}$ in. thick, having been removed by high pressure water jets, and dropped into the scale flume, which had a very fast flowing stream of water running along it; as the scale was dropped from the mill it was carried by the flow of water into the scale pit. The scale dropped to the bottom, and the degree of success in decanting depended on the speed of the water flow. To get out the very finest particles of scale was not possible economically. The flow of the water brought down the heavier pieces first, and the finer ones at the end. The reason for such care in treating roll cooling water was to remove all possible particles of scale before returning the water to the mill to prevent scale being rolled into the strip surface. It was the practice to take out the scale during the week-ends, when the mill was not working, and not during working hours.

The scale could be used in the blast furnaces at the Company's associated works.

DR. J. S. TERRINGTON (Associate Member), congratulated the authors on their work and on their paper, although, in view of their wide reputation, this was perhaps presumptuous on his part.

Referring to Part I, he said the paper indicated that in the case of the construction of the bridge, high tensile prestressing steel could not be used because the materials were not available at the time. He asked what had been lost by not having those materials. Did it mean that the use of ordinary reinforced concrete was not economic? Alternatively, did it mean that, for example, there would simply have been the additional advantage of the avoidance of cracks by the use of pre-stressed concrete?

With regard to the amenity and office building, he said the elevation (Fig. 8), showed what might well be a typical steel framed building; and one would have rather expected both the bridge and the building to have been framed in structural steel, inasmuch as they were in a steelworks. He asked if this was evidence that reinforced concrete framing was, in fact, cheaper than the equivalent structural steel frame.

Coming to Part II, it was quite clear that the form of construction gave good lighting and ventilation, but he asked Mr. Lancaster whether a plastically designed building had been seriously considered. He knew that Mr. Lancaster had been responsible for roof frames of continuous or portal type and he felt that this, coupled with the use of plastic design, might well have been employed on this occasion.

Commenting on the longitudinal section, Dr. Terrington said he had not noticed any longitudinal bracing. Would Mr. Lancaster say that he had used the strength of the stanchions to take the longitudinal inertia forces imposed by the cranes?

He was very interested in the mill building, and indeed, in the whole project; his organisation, the British Iron and Steel Research Association, had carried out tests in connection with some of the girders in collaboration with the Company's research department.

Finally he said that most other steelworks used ordinary sheeting for the walls, whereas protected metal seemed to be necessary in this case. He asked why that more expensive metal had been used.

MR. LEE, replying to the question concerning the bridge, said that throughout the whole of the work they were trying to gain time without incurring extra cost. They had placed each contract promptly after they knew for sure what work had to be done, and in the case of this bridge they were able to put in hand the contract ahead of its place in the programme. For the piers they had to dig holes over 20 ft. deep and build the bridge before the excavation was done for the railway below it. This was because the diverted water mains and electric h.t. cables under the bridge had to stay in use.

In answer to Dr. Terrington the question as to whether a structure was built in reinforced concrete or steelwork was decided solely according to availability, suitability and relative cost in each case. However, in this case owing to the spans being moderate and the continuity there was not much difference in cost but of course for greater loading and slightly longer spans there would have been definite economy by using prestressed concrete.

The office and welfare building was provided with a reinforced concrete framework because the plan did not favour load bearing walls and future alterations if necessary, would be easier; also because this contract had to follow after others and the concrete columns enabled faster progress without dependence on the brickwork.

All the foundations of the main buildings and plant had been taken down to the rock. Mr. Watkins had just drawn attention to the importance of avoiding any settlement. Mr. Lancaster would no doubt like to answer the question by Dr. Terrington about plastic design. He himself felt, however, that with heavy overhead cranes of large span—which were quite expensive—stiffness of the structure was very desirable and any economy by plastic design unlikely to be attractive relative to the advantages of low maintenance cost expected of the cranes and the cladding of the structure.

MR. LANCASTER, dealing with Dr. Terrington's question concerning cladding, said he knew that probably the majority of steelworks buildings were clad with the more commonplace materials, but the fact remained that in the particular atmosphere in which the mill building was sited there was considerable advantage in using material of the particular class that was chosen ; it gave four or five times the life.

A problem which at first sight did not seem to be very important, but was important in the event, was that of the deposition of various forms of flue dust and dirt of all descriptions, blown out from other parts of the plant on to the roof. It was just not possible to brush or otherwise remove this material from corrugated steel sheets, for example, not only because of the corrugations, but also because of the impossibility of providing the normal walkway surface on that particular area. The form of roof that was provided did help particularly in that regard. Further, he had been associated with a number of buildings on which the roof cover had been $\frac{3}{16}$ in. steel plate and, particularly where there were blast furnaces, there could be very heavy deposition on the roofs and it was necessary to use a barrow for collecting it.

Concerning longitudinal bracing, he said the building was 800 ft. long, the columns were at 32 ft. centres in general and there were sufficient columns in the length of the building to take all longitudinal crane forces.

Regarding plastic design, steelworks buildings in general were usually produced after some considerable amount of planning and thought as to their use at the outset, but there was no guarantee at all that a building would not need to have its internal shape and form considerably revised in the course of its life. So that, as mentioned in the paper, the design was a simple one, on the basis that when plant alterations or process modifications were made requiring adjustment of the spacing of columns, the crane tracks or the number of cranes, for example, adjustment could be made. That was possible to the degree that if, under certain circumstances, it became necessary to move a column 4 or 5 ft. and if the crane worked on much the same span on either side of the particular column, it was possible to invoke the virtues of continuity in welding together the sections originally provided.

There were other features which were equally important, not the least of which was that of crane maintenance. No doubt Mr. Watkins would support him in saying that crane maintenance in a steelworks could involve a very large expenditure per annum, and that expenditure could be considerably increased if there were lack of lateral and longitudinal rigidity. If the deflections were high the crane structure would be adversely affected, causing very rapid wear on the crane rails and tyres, eventually producing a crane bridge which would look like the ace of diamonds ! That, of course, was an exaggeration for purposes of illustration. 'Crabbing' was very difficult to attend to when there was some irregularity, so that where rigidity was a comparative necessity the plastic basis of design was not generally considered.

In the tests which were carried out in the plant they did not have the opportunity to take dynamic test results with the cranes, involving running them into cross travel stops under power. But this kind of thing did happen in practice with some degree of regularity in steelworks ; there was always the fellow who wanted the last half inch of travel for the crab, and in those conditions the lateral forces could be very considerable indeed.

MR. M. M. KHAN (Member), asked what consideration was given to the problem of shear resistance of the 'Castella' beams used in the roof structure, and what had been done about expansion or contraction joints in the roof girders.

MR. LANCASTER replied that this matter of the construction of expansion and contraction joints in steel superstructures had received a considerable amount of attention. Needless to say, it had not failed to attract the attention of the structural engineer who is closely connected with steelworks buildings, for he was faced with the problem of catering for a greater temperature range than in many other industrial buildings. At the Brinsworth mill, as indeed in almost every other building with which Mr. Lancaster had dealt, there were no expansion or contraction joints whatsoever. He pointed, as an example, to a melting shop structure where the length of the shop was more than a quarter of a mile and there were girders weighing 150 tons running over the tops of furnaces, and yet there were no expansion or contraction joints throughout the length of the building. There had been no indication whatsoever of buckling, distortion or the opening up of joints in the side walls or in the roof cladding.

Dealing with the question concerning the 'Castella' beams, he said the situation was that shear as such was not a vital matter in these beams. The beam is in fact a 'Vierendeel' frame in which the section is continually changing, and as the result of extensive tests it had been found that the critical issue was web buckling at the end abutment.

Extending his reply, Mr. Lancaster writes :—

For any given end load the portion of web immediately adjacent to the abutment must consist of a length of solid web amounting to 0·25 of the depth of the beam from which the castellated section is made and when the cutting of the beam does not provide this length, the required dimension must be made up by means of a welded in plate. The abutment load is divided equally between the top and bottom bridges over the castellation opening. Therefore, the web at the end is obliged to accept one half of the end load in the buckling and the web is regarded as a column having a length equal to 0·5 of the net web depth of the expanded section.

MR. F. M. BOWEN (Vice-President), said that if, as he imagined, the furnaces were oil-fired, there might be condensation in the chimney. He asked if special consideration had been given to that problem and for details of the construction. So long as the furnaces were operating full blast, the conditions would probably be all right, and he was concerned about what happened when there was a shut-down.

On the question of crab movement, mentioned on page 58 of the journal, he asked if he was correct in thinking that the gantry had been designed for the 10 per cent which was referred to there, plus a further 30 per cent of that 10 per cent for surge due to pendulum action of the lifted load.

Thirdly, referring to the detail of the heavy crane rail, he said he had gathered from the slides that the male portion was tapered in plan. He asked whether or not the rail was held down and, if so, how.

MR. LEE remarked that the answer to the question by Mr. Bowen on condensation in the chimney was not easy to make brief. He thought the thermal capacity of the chimney low enough relative to the heat from the flue gases in this case for there to be no likelihood of more than brief condensation when running up after a shut-down in cold weather.

MR. WATKINS, who also commented on this matter, said the best plan was to avoid shutting down the melting furnaces; in fact they did not close down at all, but operated continuously during the week. If they were shut down at the week-end a slow fire was kept going to keep them warm.

MR. LANCASTER, dealing with the question of crane surge, said that in this particular case the load was 10 per cent of the summation of the lifted load plus the weight of the crab. That 10 per cent was then applied to one rail, not to two, and the percentage could go up to 30 per cent of that summation, applied to one rail, in certain cases dependent on the type and operating conditions of the crane.

He illustrated, by means of a slide, the shape of the rail clip that was used, and which was welded down to the top flange. There was a small clearance between the two parts of the clip which were connected by a loose countersunk head rivet used as a shear pin.

THE CHAIRMAN, at the conclusion of the discussion, thanked the authors for their efforts in dealing with the discussion, and said he expected there would be further questions submitted in writing.

Written Discussion

DR. J. S. TERRINGTON commented that having, as he believed Mr. Lancaster knew, been associated with the Iron and Steel Industry for a number of years, having visited all the steelworks of note in Great Britain and been concerned with structural tests on many of the gantries, he fully appreciated the need for correct alignment of crane rails and rigid gantries. His proposal with regard to plastic design was that the gantry stanchions and girders up to crane level should be elastically designed as at present, allowing for fatigue effects as necessary (since such effects were very much in evidence). Above crane rail level, the roof legs and roof over would then be plastically designed as 'portal' types. The point was, of course (as is well known), that the roof and roof legs above crane level do not contribute any rigidity to the crane gantry; the rigidity and alignment of the gantry being afforded solely by stability of the gantry stanchions as columns fixed at their bases. This aspect had been agreed by others in earlier discussions. This being so, the superstructure above crane level could be simplified and cheapened, as has been done on the Continent and in at least one of our smaller steelworks—and certainly in many works outside the Iron and Steel Industry.

MR. LANCASTER writes :—

In reply to Dr. Terrington on the further question of plastic design for the 'above crane rail' portion of steelwork structures, there is no doubt that plastic design is a possibility. Whether in fact it would be quite so satisfactory over comparatively long spans is by no means so certain as there are many factors controlling the choice of method in such a structure. It is agreed that up to crane gantry level the structure must be entirely self-supporting from foundations and that no allowance be made for any roof work action. Nevertheless, it is extremely important, especially when large glazed areas are involved, that any vibration coming from the gantry should be minimized to the greatest possible extent. Deflections too must be maintained at a reasonable minimum in order to provide an overall rigidity to the building.

This is perhaps a point which may be argued in alternative ways, but it is felt in this instance that from the point of view of long term maintenance there is a great deal to be said, and maintenance costs may be very considerably reduced by providing a roof structure of considerable rigidity rather than to save a comparatively small amount of capital expenditure and find that over the years the maintenance necessary to keep the building in a satisfactory condition is very considerably larger than the original economy. It should be borne in mind that to continue a twenty-four hour day operation of cranes throughout the year presents a very considerable problem in structures of this type under the conditions generally obtained in steelwork structures where production is of paramount importance. Any maintenance required may have very serious consequences on production time, should the roof and upper side framing prove to be anything other than perfectly water-tight over a long period of years. It is with this object in mind that elastic design was employed on this particular building and indeed has over the years proved itself to be an advantage.

Book Review

International Association for Bridge and Structural Engineering Publications, Volume XIX, 1959. (Zurich : Verlag Leemann, 1960). $9\frac{1}{2}$ in. × $6\frac{1}{2}$ in., 296 pp., 168 figs., S.Fr.40.

The nineteenth volume of "Publications" contains fifteen papers. Twelve of the papers are in English, the contributions dealing with : Theory of trusses, secondary moments, end rotations, inflections points and elastic buckling load of truss members, application of Donnell's theory of circular cylindrical shells to the analysis of curved edge disturbances, the design of frameworks to give specific deflections, vibrations of bridges with continuous main girders, theoretical and experimental researches on continuous box girder bridges, a criticism of the plastic-hinge concept used in the plastic theory of structures, bending of partially loaded simply supported cylindrical shells, the effects of edge-stiffening and eccentric prestress in bridges, on the analysis of a skew girder bridge by the theory of orthotropic parallelogram plates, deformation of ring girders stiffening thin shells of rotation, and on boundary conditions in the bending of thin elastic plates.

One paper in French is on orthotropic plates and orthotropic cylindrical shells with asymmetric ribs, and two papers in German deal with the continuous Vierendeel girder and the relaxation of steel wires.

Each article is followed by a summary in English, French and German.

New Developments in Structural Analysis and Design by Means of the Electronic Computer

Discussion on the following papers :- *

(1) **Application of an Electronic Digital Computer to Structural Steel Design, by L. Morgan.**

(2) **The Analysis of Grid Frameworks and Floor Systems by the Electronic Computer, by E. Lightfoot, M.Sc.(Eng.), Ph.D., M.I.Struct.E., A.M.I.C.E. (Delegate Member of Council) and F. Sawko, B.Sc.**

(3) **Elastic Critical Loads of Multi-bay Pitched Roof Portal Frames with Rigid External Stanchions, by D. M. Brotton, B.Sc., Ph.D., A.M.I.Struct.E.**

Discussion

THE CHAIRMAN proposed a hearty vote of thanks to the authors for the considerable amount of work they had put into the preparation of their papers and for the way in which they had presented them.

DR. R. K. LIVESLEY (Cambridge), in a contribution presented on his behalf by Mr. J. D. Renton (Research Student), stated how extremely sorry he was that he was unable to be present at the meeting. It was one of the most pleasant experiences of a research worker to find that his ideas had proved useful to others, especially when he saw in their work variations and extensions which he would never have thought of himself !

One of the characteristics of the generalised slope-deflection method of structural analysis was the way it led to flexible computer programmes. This, he thought, was due to the fact that it separated out the physical properties of the individual elements of a structure from the overall pattern of joint connections. The stiffness matrices of the elements were usually computed by a sub-routine and varied according to the type of structure, but the assembly of these elementary matrices into a complete set of equations was dependent only on the topology of the structure, not on its geometrical shape. Thus Dr. Lightfoot and Mr. Sawko had found it easy to convert the original plane frame programme into a grillage programme, and it would be equally easy, if one wished, to carry out a further metamorphosis and produce a programme for pin-jointed space-frames.

One of the points in Dr. Lightfoot's paper which opened up many interesting possibilities was the use of grillage programmes for solving plate problems, and the analogous use of plane frame programmes for solving problems of plane stress and strain. It would be very useful to see how these 'finite element' methods compared with the older 'finite difference' methods from the point of view of accuracy for a given mesh size; he was certain the new methods were superior in their ability to deal with such effects as non-uniform plate thickness and curved boundaries.

It should be noted that a square mesh grillage was not an ideal representation of an elastic plate. Although one could certainly include torsion about the axes, one still did not obtain any anticlastic curvature when bending took place about one of the axes of the grillage. The behaviour in such a case corresponded, therefore, to that of a plate with zero Poisson's ratio. One could obtain a better representation by filling in the diagonals of the grillage with beams of appropriate stiffness.

Another method of representing a continuous plate which had been used successfully at the University of California was to employ, not line elements, but small square or triangular plates. These were assumed to be connected only at their corners, so that one still had a problem with a finite number of variables. Professor Clough had told him that he hoped to publish this work at the autumn conference on electronic computation of the A.S.C.E.

Dr. Livesley concluded his remarks with a very brief account of the programmes which had recently been developed for E.D.S.A.C. II at Cambridge. These were :—

1. A linear plane-frame analysis programme. This was merely an improved version of the original Manchester programme, the only novel features being an allowance for rigid joints of finite size and an automatic built-in check for joint equilibrium applied to the computed moments and forces.

2. A programme for the elastic-plastic analysis of plane frames. This was an extension of the original elastic stability programme developed at Manchester to include the effects of plastic hinges. It was described at the recent conference on structural computing, at Southampton.

3. A programme for investigating the out-of-plane stability of pin-jointed trusses.

4. A grillage programme similar to Dr. Lightfoot's produced by modifying the first programme mentioned.

It was hoped shortly to begin planning a comprehensive programme for investigating the stability of space frames; this was bound to be an undertaking of some size and he would not like to guess when it would be completed.

Finally he asked Dr. Lightfoot and Dr. Brotton, as fellow University teachers, for their opinion on the effect which all these developments ought to have on our teaching of structures at both the undergraduate and post-graduate levels.

DR. LIGHTFOOT said that Dr. Livesley was specially invited to the meeting because he was the originator, in this country at least, of the application of the

* *Read before The Institution of Structural Engineers, at* 11, *Upper Belgrave Street, London, S.W.*1, *on the* 10*th March,* 1960. *Lt.-Colonel G. W. Kirkland, M.B.E.(Mil.), M.I.Struct.E., M.I.C.E. (Vice-President) in the Chair. Published in "The Structural Engineer," Vol. XXXVIII, No.* 3 (*March,* 1960).

electronic computer to structural analsyis; he was also a genuine programmer, whereas many of the rest of us were no more that interested by-standers. It was a pity that a recent injury detained him at Cambridge, but we were all very grateful to him for his illuminating contribution.

Actually, the authors of the second paper were already aware of some of the applications mentioned by Dr. Livesley. Though they had realised the possibility of applying the grid frameworks programme to the problem of the lateral instability of rigid frameworks they had not yet got it completely programmed. They had, however, been able, in the Department of Civil Engineering at Leeds, to develop Dr. Livesley's plane frameworks programme to allow for the presence of curved members of varying section. Also, quite recently, Mr. Sawko had developed the grid frameworks programme to allow for lateral elastic supports at the joints; it was thus possible to determine the behaviour of circular tank walls and of grid frameworks acting as foundations. A paper on this latter topic, using the well-known relaxation method was quite recently presented to the Institution of Civil Engineers, but this type of problem could now be solved very easily on the computer.

One of the biggest problems with a major development like electronic computing, is finding time to follow up all the possible applications. More research workers and programmers are urgently required to translate hypothetical developments into real achievements in the form of readily available and really useful master programmes.

At the meeting Dr. Lightfoot remarked that Dr. Livesley's question about the effect of the electronic computer on the teaching of structural theory at the universities required very serious consideration. For the moment he preferred to leave it in case any members had come along to the meeting with technical comments, questions or arguments about the content matter of the three papers. In a further written communication he added that in his view the entire presentation of structural theory needed to take account of the facilities offered by the electronic computer. The generalised slope-deflection method for framed structures and the matrix formulation and solution of the Maxwell-Mohr virtual work equations (which were mentioned later in the discussion by Mr. Munro) certainly needed to be included in any modern treatment of structural analysis. There was a case for emphasizing the 'elemental' methods which the computer utilized and the successive correction methods which were usually the most speedy and satisfactory for hand computation (preferably by slide rule).

So far, at the University of Leeds, degree students have been shown how to obtain solutions from the computer by the use of master programmes (as a convenient check on certain previous moment distribution or experimental analyses). A computation class is now included in the final mathematics course for Civil Engineering students, as a continuation of a class on numerical mathematics. In this class the students are taught how to use the autocode facility on the Pegasus machine, and the principles of the design and operation of electronic computers are also explained. The development of new or the extension of existing programmes will be left to the post-graduate stage (except, perhaps, on autocode). It is thought that this coverage, in the structures and mathematics classes, is sufficient for the present.

Dr. Brotton said that at the College of Science and Technology at Manchester, this year for the first time, there was a number of students who were completing a degree course with a specialised option on Structural Engineering. At the beginning of the year it had to be decided what should be put into the Structural Design syllabus. Various members of the department had specialised experience on structural steelwork, reinforced concrete, electronic digital computers and so on. A composite course of lectures had been arranged comprising a number of sub-courses on these topics. It was decided that it was impossible to include any computer programming since this would have considerably overloaded the course, however, three lectures had been allocated to cover the application of digital computers to structural problems. In addition a sound basic course on numerical analysis comprising one lecture per week throughout the session was given. It was thought that this would give the students an appreciation of the value of computers and the mathematical ability to make use of them at a later date.

With regard to plastic hinges, he said the results in his paper were obtained from work carried out on the old Ferranti Mark I machine, using Dr. Livesley's own programme; but that programme did not have the facility for dealing with members which were rigid at one end and hinged at the other, so that he was not able to include the effects of plastic hinges in those results. They had since prepared a general framework analysis programme for operation on the Ferranti 'Mercury' computer. This programme was able to deal with members which were rigid at one end and hinged at the other end, the stiffness matrix for these members being different from that for members which were rigid at both ends. The programme was able to set up the relevant matrix and assemble the equations in exactly the same way. A 'stability version' of this programme would be able to do what Dr. Livesley had suggested.

The question of out-of-plane buckling was also mentioned in Dr. Livesley's contribution. The determination of the out-of-plane buckling loads for rigid jointed portal frames was difficult and it would obviously be of value to know their values, but he did not think that anyone knew sufficient about the problem yet. It was true, even when the joints were fully restrained against lateral displacement, say by suitable rafter and side bracing, that lateral buckling might occur before other modes developed. The engineer however, guarded against this intuitively by providing small ties from the purlins and girts. There was obviously a need for further research into this problem.

Mr. J. D. Renton asked Dr. Brotton whether he thought it was of value to extend his analysis of portal frames to include the possibilities of lateral buckling and the development of plastic hinges.

He pointed out that Masur and Cukurs* had shown that even when the joints are fully restrained against lateral displacement lateral buckling may occur before other nodes develop.

Dr. Z. S. Makowski congratulated the authors on producing such a fine paper. In his opinion it was a very important paper, clearly demonstrating the enormous potential possibilities of an electronic computer in the analysis of complicated grid frameworks.

Dr. Makowski was interested in the paper for various reasons. Since 1951, he has been in charge of a postgraduate course on structural analysis of grids and interconnected bridge girders at the Imperial

* E. F. Masur and A. Cukurs, "Lateral Buckling of Plane Frameworks." (Proceedings of the American Society of Civil Engineers, *Engineering Mechanics Division*, I/57.).

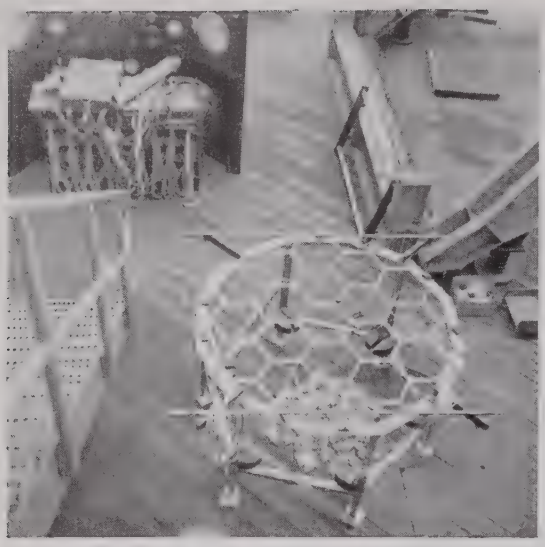

Fig. 1.—Model of a plane grid of a regular hexagonal layout.

College. During this course various methods of analysis of grids were discussed and compared. Special tables have been prepared for rapid analysis of various types of grids. As a matter of fact, the diagonal grid, shown in the authors' paper as example 2, is one of the first standard cases which the students have to analyse during their course.

The authors were quite right in stressing the difficulties of analysis of grid structures, but they tended to over-emphasize their point.

It was difficult to agree with the authors that only since the advent of electronic computers was it possible to analyse these complicated structures, e.g. the authors stated that grid frameworks "previously proved unsuitable for moment distribution or any other really easy methods."

It was an overstatement, as moment distribution methods had been used for the last ten years or so very extensively in the analysis of grids in various countries, and they had proved to be very powerful and quite simple, if applied in the proper way. Especially grids with negligible torsional rigidity could be analysed very quickly by various methods.

The authors concentrated on only a few different types of grid frameworks but quite rightly emphasized the point that there were many unexplored structural and architectural possibilities for grid frameworks

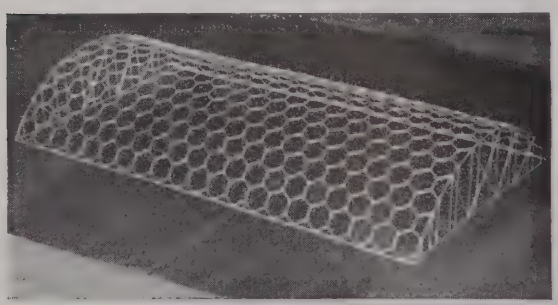

Fig. 2.—Model of a braced barrel vault—an example of a space hexagonal grid.

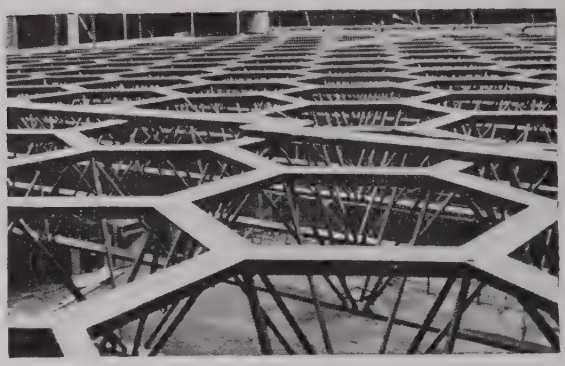

Fig. 3.—Prefabricated hexagonal grid covering the Conference Hall in the T.U.C. Memorial Building in London.

and that the use of electronic computers would allow the application of rational design of such cases.

It might be of interest to mention that at the moment extensive research was being carried out at the Imperial College on plane and space grids of a regular hexagonal layout in the analysis of which the electronic computer played an extremely important role. (Figs. 1 and 2).

A very interesting space hexagonal grid had been constructed recently in London in the T.U.C. memorial building over the conference hall. It was designed by Ove Arup and Partners. (Fig. 3).

Another interesting example was provided by the three-way prefabricated steel grid covering a church in Chartres, in France. (Fig. 4). Monsieur S. du Chateau, of Paris, was the architect for this structure, which had been analysed for various loading conditions by Dr. Makowski. He showed a number of slides illustrating the stress distribution in this grid under u.d. loading covering the whole area, and also under several unsymmetrical loading cases. The grid was now under construction.

The design of this structure was a very good example of the tremendous influence that electronic computers exerted in the analysis of complicated structural systems. Owing to a very high number of simultaneous equations, set up during the analysis, such structures could not be tackled in the past without some sweeping approximations. Now, using an electronic computer, they could be analysed with a great accuracy in a very short time.

Dr. Makowski pointed out that there were several ways in which the designer could avail himself of the electronic computer. The simplest one, perhaps, was the use of the computer for the rapid solution of simultaneous equations, set up during the analysis of highly redundant structures.

The more advanced one was the preparation of a programming for certain types of structures, feeding in the data and getting out of the computer the numerical values of bending moments, axial forces, deflections, etc., as discussed in Dr. Lightfoot and Mr. Sawko's paper.

Finally it was possible, as had been shown by Mr. Morgan in his paper, to prepare the programme in such a way that the computer not only did the analysis, but also did the design, providing the operator with the final sizes of the beams.

In Dr. Makowski's opinion, most practising structural engineers would be more interested in using an electronic computer to solve simultaneous equations.

Fig. 4.—Plan of a Church in Chartres, France, covered with a three-way grid.

The preparation of the programmes was still quite a difficult procedure requiring a computer specialist working in close collaboration with the engineer—an approach which had its advantages, when applied to cases in which many structures of a similar layout had to be designed frequently, but this could prove too expensive, if only one structure of a particular type had to be considered.

The situation would be better in the future, as it might be possible to arrange to have various programmes in a central library and loan for a small fee.

At the moment, according to Dr. Makowski's information, the preparation of a really useful programme might be quite expensive.

It had to be realised, however, that there were many advantages, if such a general programme was available. It would be possible to prepare very easily a family of curves, showing the influence upon the stress distribution produced by the variation in the rigidities of the members, methods of support along the boundary, etc.

This would enable the designer to select the most economical solution under any particular loading condition.

Space grids of double layer were becoming very popular, especially for covering large spans. As a rule they consisted of prefabricated units (Fig. 5). Being very rigid, their deflections were of no concern in the design, and being of a double layer type these structures exhibited a remarkable resistance against overall buckling.

The studies carried out at the Imperial College indicated that in this form of construction the rigidity of connections did not influence to any noticeable extent the axial stresses. Tension or compression was then the principal stress resultant in the members of the grid.

A preliminary design of such a space grid, illustrated in Fig. 6, made recently by Dr. Makowski for an exhibition hall in Oyonnax, France, according to the layout prepared by M. S. du Chateau, indicated that this type of space grids resulted in a very efficient and light form of covering large spans.

Owing to the very large number of bars forming space grids their analysis by the orthodox methods was extremely difficult. Therefore it was not surprising that various approximations, often of a very doubtful nature, had been used by the structural engineers in the design of these structures.

Being very interested in the analysis of space grids, Dr. Makowski would like to ask Dr. Lightfoot, whether a programme for electronic computers had been ever considered by anybody in this country for this type of construction.

In the U.S.A. a number of extremely interesting braced domes had been built during the last few years in steel, aluminium, and other structural materials. (Figs. 7 and 8).

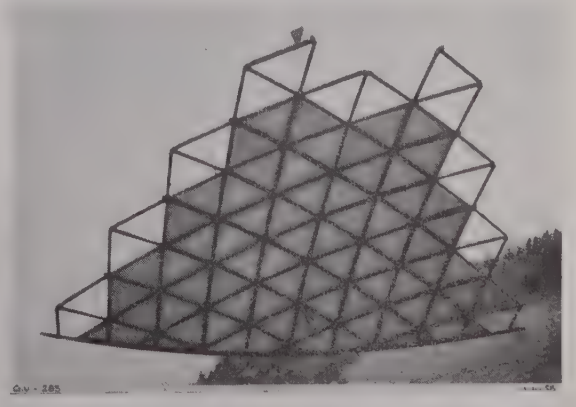

Fig. 5.—Lifting up of a prefabricated steel grid.

Fig. 6.—Perspective of a double layer grid covering an exhibition hall in Oyonnax.

The maximum span reached so far was 384 feet. Most of these domes were space grids of double layer and though their design was very difficult, they had proved to be more economical than conventional methods of construction.

One particular type was readily available at present in six basic sizes, four approximately one hundred to two hundred feet in diameter. (Figs. 9 and 10).

The question of preparing a general programme for electronic computers for such structures had been raised and seriously considered by various large firms, but somehow a rather depressing conclusion had been reached that a special computer should have been built for the analysis of such systems and the high cost would prove prohibitive for a private firm.

This was the present situation, but no doubt, with the rapid developments taking place in the field of electronic computers the situation might change radically during the next ten years.

Dr. Lightfoot said how grateful he was to Dr. Makowski for his contribution which was really deserving of a separate paper.

The authors had tried to point out that their electronic computer programme for the analysis of grid frameworks was even more advantageous in relation to previous methods, than the plane frameworks programme. The reason for this was explained in the first paragraph of section 4. The senior author was a practising advocate of the moment distribution method but that did not blind him to its limitations, one of which was its unsuitability for the speedy analysis of grid frameworks. Whether torsional strength was disregarded or not in a gridwork an unknown 'sway' deflection occurred for every joint without lateral support; moreover, the relevant moment-sway equations were all 'coupled' so that it was—apparently—impossible to devise a method to enable the joints to be balanced for moments without disturbing shear equilibrium. Thus only the unit sway and successive shear correction methods were applicable, the first requiring as many simultaneous equations as there were degrees of sway freedom and the second proving to be disappointingly slow in convergence. The authors were aware of the various papers which had been published on the application of moment distribution to grid frameworks; they were all simple enough in conception but dreadfully tedious in their numerical application. A realistic usage of moment distribution was fairly recently demonstrated by Reddy and Hendry in a paper in *Civil Engineering and Public Works Review*, July-August, 1959; there the moment distribution method was applied merely as a final improvement on an approximate solution obtained by a different method.

This criticism of the moment distribution method for grid frameworks was made with rectilinear gridworks in mind; if, say, hexagonal gridworks were to be attempted the difficulties of the moment distribution method would be considerably increased. The computer method presented in the paper applied just as easily however the various members were orientated on plan.

Dr. Makowski had shown a number of very interesting slides of space frameworks. These structures were often very beautiful and Dr. Makowski had been most fortunate in collaborating with the adventurous architects who had created such exciting forms. In analysing such novel structures at odd intervals one would naturally look for a method which exploited existing facilities and Dr. Makowski had, apparently, often used an electronic computer for dealing with the simultaneous equations and a hand calculating machine for the remaining computations. This same method had been applied by the senior author in the analysis of rectangular tanks under hydrostatic pressure and was a satisfactory method for occasional problems. With improvements in the capacities of the larger modern computers, however, the time had come for a general programme for the analysis of space structures. The general theory for space structures had therefore been included in the paper to show that there were no special difficulties in it; plane and grid frameworks are merely particular cases which require only three rather than six equations at each joint and which,

Fig. 7.—Double-layer grid dome in Baton Rouge, Lu., U.S.A. Span = 384 ft.

Fig. 8.—Double-layer space grid covering the American Society for Metals building in Cleveland. Span = 250 ft.
Architect : Y. T. Kelly.

being easier, have already been programmed. If 'pinned' rather than rigid joints were assumed to occur in any space framework then only three equations would again be needed at each joint ; a programme for this special type of structure would be sufficient for some of the frameworks considered by Dr. Makowski where the members are so arranged and orientated that appreciable sidesway deformations are prevented. It would be relatively easy to adapt the Pegasus plane frameworks programme for the analysis of pin-jointed space frameworks of this type, as Dr. Livesley observed earlier. The electronic computer has, in fact, already been applied for this sort of analysis in the U.S.A.

It was not surprising that private structural firms had found it uneconomical to attempt the development of large master programmes and the computers to work them. This facility might yet be offered to engineers by specialist programming consultants, on a commercial basis. Perhaps the major engineering institutions might be prepared to sponsor the production of master programmes for large standard machines, when there is sufficient demand from their members. The plane and grid frameworks programmes are already freely available for the Ferranti Pegasus machine.

Dr. E. H. Bateman (Member), pleaded that we should discontinue the use of the word 'space' from terms such as 'space grid' and 'space frame.' We should remember that since 4th October, 1957, the word 'space' had taken on a new meaning ; it now related to an extra-terrestrial in which the Russians and Americans played a new kind of ball game, and 3-D would be much more appropriate.

Mr. R. F. Godman (Member), remarked that speaking as a 'mere engineer' he would like to have in the office some of the designs that had been discussed and illustrated. The difficulty was to get hold of them rather than design them !

As a prospective user of a computer, he mentioned the design of supension bridges which by electric desk calculating machine took about two months to

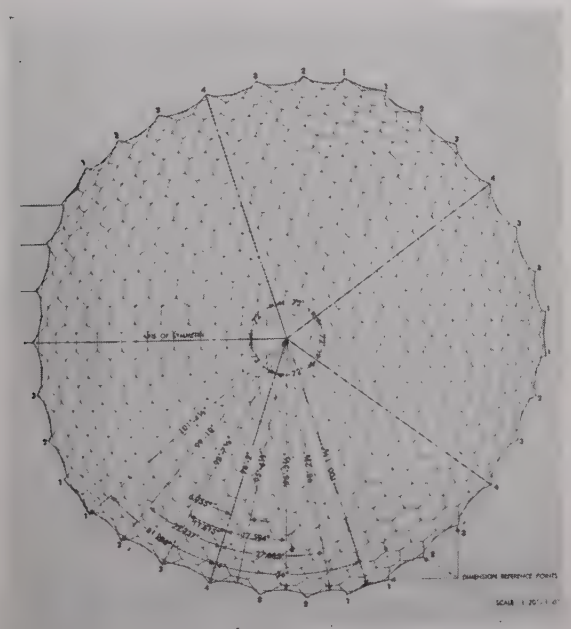

Fig. 9. — A typical layout of a Kaiser Aluminium dome. (*Plan*).

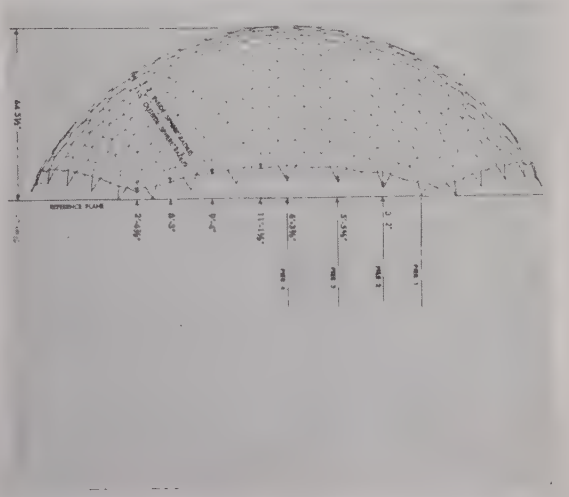

Fig. 10.—An elevation of a Kaiser Aluminium dome.

design. The programme had taken them two and a half months to write, but no doubt they would have the benefit of this in the next design.

Another point he had in mind was the effect of all this on young engineers. If an engineer in the future had to design a complicated structure his greatest difficulty might be to find where the programme was filed! He might perhaps know very little about the actual design.

Mr. Morgan said he was very pleased to hear that structural engineers were applying the computer in other directions. When considering the advisability of writing a programme to do a specific job one had to consider the time it would take to write it and the frequency with which the problem would occur. If one could produce a programme in the same time as one could compute the problem manually then there was no question that it was better to adopt a first course. One was then equipped to deal with a similar problem the next time it arose and there was nothing lost if it did not. One must take also into account the chances of subsequent modification to the detail of one's problem. It was a simple matter to change numbers on a data tape, whereas it might be quite a laborious task to recompute manually.

There is a natural tendency to be afraid of something which one does not understand, but computers hold no terrors for those who are prepared to use a little initiative, and attempt to make use of them. The engineer should not be dismayed by the sterling efforts of the mathematician.

The design staff of the United Steel Structural Company had not received any special training in the detail of programming. Despite this they had themselves produced, during the past nine months, thirty autocode programmes, guided only by the maker's instruction manual. They were of course computer conscious, having seen it in action, and had excellent relations with the programming staff in Sheffield. They started with easy problems mainly concerned with the production of tables of design data required for use with the new B.S.449, or calculating sectional constants for new ranges of Castella beams. The fourteenth programme, however, was the column design programme which was by no means simple, even in its early stages of development. Today it still exists in its autocode form, although it is scheduled for conversion to machine orders by their colleagues in Sheffield.

Autocode was a simplified form of programming, rather like basic English in that it had similar advantages and disadvantages. It was easy to learn and quick to write, but having a smaller vocabulary it might take more words (or orders) to describe what one wished to do. Autocode programmes took longer to run than their equivalent in machine orders but this might not be significant in small programmes and generally the advantages outweighed this.

During the course of a morning some two or three months earlier, the Chief Designer was asked if he could assist in producing moments of inertia at stations along the length of a bridge girder. It was of the anchor and cantilever type, the profile of which consisted of an arrangement of straight lines, arcs of circles and ellipses and a cubic curve. It was 120 ft. long and of varying depth from end to end. Starting from scratch, i.e. writing the programme, the overall time, including in this case postage to and from the computer, was less than forty-eight hours. Had the job been urgent it might have been done in twenty-four hours using a faster means of communication. Not only were the inertias at 1 ft. 6 in. intervals found, but, as a bonus, also calculated were the offsets to top and bottom flanges from a horizontal datum; the weight; the centre of gravity; the abutment reactions; and shear and bending moment diagrams for self-weight. Some time later the profile was altered, the programme was amended in a few minutes and the computer obliged again with the modified answers.

That was all very well for those with access to a computer. For those who had not this facility at hand, there were people in business for the sole purpose of supplying it. If one wrote one's own programme one might find their services an economic proposition.

But that was the brighter side of computers, there is a potential dark side which Mr. Godman had exposed. A fair proportion of the staff in design offices learnt their trade by doing the job. Was the advent of the computer going to remove the training ground? The most advantageous combination of man and machine was to arrange for each to do that part for which they were best suited; the man to do the thinking, the machine to do the work. Many of the decisions that the man must make were based upon experience he gained doing the work. Were future designers to lose this experience?

In reply to Mr. Godman, Dr. Brotton added that it was hoped to have some programmes for the solution of suspension bridge problems available before long. Several organisations had compiled and circulated details of the programmes available to those who intended to use computers.

Another point worth mentioning was the importance of making the computer do as much of the work as possible; programmes should be written so that the data which was presented to the machine was in as concise a form as possible, this reduced the time spent in data preparation and considerably reduced the chances of errors.

Mr. John Munro (Associate Member), congratulated the authors on their interesting papers. Dr. Lightfoot and Mr. Sawko had discussed first the requirements of a general programme for skeletal structures and then proceeded to describe a special programme for the analysis of planar grid structures with normal loading. The programme was confined to grid members which were prismatic.

Mr. Munro said it was well known that there were two basic methods of linear elastic analysis of skeletal structures—the flexibility method and the stiffness method. The stiffness method had advantages where prismatic members were used, since the beam stiffnesses could be derived immediately and the stiffness matrix of the structure obtained by manipulation of the member stiffnesses. This method has been used successfully both in this grid programme and in the Livesley programme for planar skeletal structures. The flexibility method has the initial disadvantage that a particular solution for a suitably reduced structure must be modified by an appropriate set of complementary solutions and, in general, numerical integration is used to obtain the elements of the flexibility matrix of the reduced structure. However, in the application of a stiffness method to the general case mentioned in the introduction to the paper, it would be necessary to perform similar integrations along each member to obtain the member stiffness and build up the stiffness matrix of the structure as before. In such cases the flexibility method would appear to have some advantages and there is available a simple flexibility programme[1,2] which can deal with (a) planar and non-planar structures; (b) general loading; (c) curved members; (d) continuously or discontinuously varying sections; (e) bending, shear,

twist and thrust energies as required; (e) prestressing and (f) temperature effects. With some minor modifications it can also deal with settlement of supports and lack of it. In addition, it can be shown[1,2] that for rigid structures, the flexibility method leads to a much smaller indeterminacy number and hence fewer equations. Such a method gives considerable scope for engineering judgment in the omission of obviously negligible energies and by this and other techniques, such as the use of symmetry, the demands on the computer's storage capacity can be reduced. In Example 1 in the paper, the author's method led to an unnecessarily large use of the computer's storage and had necessitated partitioning. The flexibility method could have taken advantage of the negligible torsional stiffness and this particular problem could have been solved simultaneously for many loading conditions without resorting to partitioning techniques. Mr. Munro asked Dr. Lightfoot and Mr. Sawko whether they had considered the relative merits of the two methods for the general case, and, if so, what were their conclusions.

Dr. Lightfoot replied that he would not like to embark at that moment on a complete comparison of the two methods. The great advantage of the slope-deflection, i.e. the stiffness, method was that it was considered each *separate* structural element and one could think in terms of separate elements, whereas with the flexibility method used by Mr. Munro, as developed by Professor Argyris and Imperial College, one had first to consider the effect of the loading on some statically-determinate counterpart of the actual structure and then start applying and determining the effect of each redundancy as well. This meant, in fact, that every structure analysed by this method had to be specially considered and the various matrices had to be correctly obtained and used in each problem. With the authors' method the physical data for the structure could be written down without any appreciable mental effort, whereas with the flexibility method a partial structural analysis had to be correctly accomplished and a considerable amount of derived data had to be prepared for the computer.

The two methods were sometimes compared, in a very rough sort of way, by the number of simultaneous equations involved in the solution. In certain cases, such as a grid framework with the torsional strength neglected or a pin-jointed truss with redundant bars, the flexibility method might require fewer equations, but for the rigid-jointed plane or grid framework the stiffness method usually requires no more equations, even in the completely general methods used in the master programmes. But, provided the capacity of the programme was not exceeded, this question of the number of equations was of little concern to the user. The computer took longer, of course, with a larger number of simultaneous equations to solve, but this was usually of small concern when reckoned against simplicity of data preparation. The flexibility programme for the Ferranti Pegasus machine requires the use of a special matrix interpretive scheme and may even require more machine time, in comparable cases.

1. Henderson, J. C. de C., Edwards, A. D., and Munro J., "An application of an Electronic Digital Computer to the Linear Analysis of Skeletal Structures," *Concrete Technology Report No.* 1, Imperial College, London, S.W.7, April 1959.
2. Henderson, J. C. de C., Edwards, A. D. and Munro, J., "Influence Co-efficient Methods of Linear Structural Analysis," *Symposium on the Use of Electronic Computers in Structural Engineering*, Southampton University, September, 1959.

The first and second examples in the paper were included to demonstrate the grid frameworks programme in straightforward cases. Even so, and with torsional strength neglected, the flexibility method requires sixteen and eleven simultaneous equations to be solved, respectively, in these two cases and a certain degree of skill is required in writing out the various corresponding matrices. The authors' grid frameworks method requires virtually no skill in preparing the data for the computer. Partitioning is required for the first example, but this is simple enough and involves hardly any additional work in presenting the data. There are further points worth mentioning: firstly, the output from the grid frameworks programme is self-explanatory and includes deflections and angular deformations, if these are required; secondly, had the members been orientated at odd angles, i.e. had not been rectilinear, this would have been an awkward complication in the flexibility method but is automatically allowed for in the authors' method.

It is apparent that Mr. Munro and the authors have different conceptions of an electronic computer master programme. The authors' grid frameworks programme, like Dr. Livesley's and Mr. Rooney's plane frameworks programmes before it, requires only the input of basic data and provides the output of the results in a tabulated, self-explanatory form. Mr. Munro's programme, on the other hand, is no more than a few instructions involving present parameters for the matrix interpretive scheme, the necessary data has to be computed by hand as a number of partial analyses which are compounded by the machine. His programme is, in fact, no more than a *procedure* for utilising the matrix interpretive scheme and requires much more skill and effort from the operator than is usually expected with a master programme for an electronic computer. With this in mind it is possible to understand the claim that 'there is available a simple flexibility programme which can deal with . . .' This is not a master tape which can be sent through the post but a formulation of the necessary procedure in matrix form. The authors mentioned that a real master programme was required to allow for all the possible structural variations and effects in a single member. This has already been written to allow for a curved centre-line and a variable section with deformations due to bending and axial forces considered; it requires no more than the insertion of the data of the problem and is automatically included in the plane frameworks programme. It has yet to be extended to allow for a member of variable section curved in space, for lack of fit, prestressing rise or fall of temperature, and with bending, shearing, twisting and axial deformations all considered. When this completely general programme is evolved it will require no more than the input of the relevant data and will involve no supplementary, partial structural analysis.

The authors would, however, like to acknowledge the value of the flexibility method in its many successful applications, though they consider that the computer should, wherever possible, be programmed to accept basic data and to print-out fully annotated results.

The Chairman, in closing the proceedings, said he felt that the discussion had been a great reward to the authors for all the work they had put in. All present must feel very appreciative, and he was sure they would wish to join him in extending their very grateful thanks to the authors for the way in which they had handled the discussion.

Research for the Concrete Industry *

Discussion on the Paper by A. R. Collins, M.B.E., D.Sc., M.I.Struct.E., M.I.C.E. (Member of Council).

THE PRESIDENT, proposing a vote of thanks to Dr. Collins, said that, as stated in the paper, research on a scale such as he had discussed could not be described adequately unless only a certain short term of years was covered at a time, and it would be agreed that he had dealt with it adequately in this paper.

In his usual breezy style he had presented it and had illustrated it with some coloured photographs, which had added so much to the interest of the papers presented during the session. Further, the presentation of his subject was remarkably entertaining. He had made the point, which was typical of the man, that he was the spokesman of a team, and the President invited the meeting to express appreciation of the spokesman.

(The vote of thanks was heartily accorded).

DR. COLLINS expressed his appreciation and thanked the Institution for the co-operation it had given his organization over the last ten years or so.

DR. T. W. PARKER thanked the Institution for having allowed him, a non-member, to attend the meeting and to take part in the discussion.

As had rightly been said, it was difficult to comment on so considerable a programme as that described. Those who had seen the work of Dr. Collins' team over the last ten years had acquired a considerable admiration for it.

Speaking of the permanent demonstrations at Wexham Springs, Dr. Parker said that the results of applied research were only useful when they were, in fact, applied, and it was right that the various institutions should take a great deal of care to ensure that the industries in which they were working could be persuaded to assimilate those results. A demonstration, such as that on exposed aggregate concrete, was a very good means for promoting use in the building industry.

On the question of the distribution of research effort, he believed it was well known and accepted that, in proportion to the value of the building and civil engineering industry, the amount it spent on research was much less than the average for the country's industries as a whole. In spite of the imaginative gesture of the cement manufacturers in sponsoring research on the uses of cement, the Cement and Concrete Association, the Road Research and the Building Research Laboratories together did not cover all the possible items that needed study; therefore, some selection had to be made. Dr. Parker did not wish to offer criticism of the Association's particular selection. He knew of the many mechanisms provided to help the Director of Research of the Association in the selection of research programmes, but he thought that it might nevertheless be useful to contribute some facts which might influence future programmes.

In 1950 he had wondered what was the distribution of research effort in building and civil engineering and he had tried to arrive at it by analysing the list of papers published in that year by *Building Science Abstracts*, which had a fairly comprehensive coverage. He had found that, of the total number of papers on research in building and civil engineering, about 59 per cent related to materials of structures. That was a relatively high percentage. For example, rather more effort was devoted to that form of research than to the services in buildings—heating, and so on.

Of the total papers dealing with materials, something like 26 per cent in 1950 related to cement and concrete; this again was slightly favourable as compared with other materials used in building, since as far as he could judge from information from two separate sources, the amount of cement and concrete materials used last year, in terms of cost, was somewhere between 17 and 24 per cent of the total materials used in the building and civil engineering industry.

How far could such statistics aid us in carrying out a research programme? He agreed with Dr. Collins that there were times when a rush programme had to be devised, such as that in connection with prestressed concrete, in order to meet the needs of practical developments. Programmes might also be put in hand well in advance of popular knowledge; others might depend a great deal on some special skill or brilliance of the laboratory in some specific aspect. In addition to all this, we might expect the kind of research done, or the relative effort on it to reflect the distribution of the actual use of the materials to some extent.

In this country we made annually between 30 and 40 million cubic yards of concrete. The Building Research Station had recently had facilities from contractors and others which had enabled them to make a better analysis of existing materials, and of costs of materials and labour, on certain buildings, and they had been able to deduce the distribution of the uses of cement.

Dr. Parker showed tables showing assessments, first, in terms of the kind of buildings, secondly the kind of concrete, and thirdly the method of using concrete.

Estimated Consumption of Cement

1959

By Type of Building

Houses and Flats	25—30%
Factories	15—20%
Offices	15—20%
Roads	5—10%
Power Stations	5%
Railways	2—3%
Schools	3—4%
Sewerage and Work	3%
Asbestos Cement	3%
Unaccounted	10%

* *Read before the Institution of Structural Engineers, at* 11, *Upper Belgrave Street, London, S.W.*1, *on the* 24*th March,* 1960. *Mr. Lewis E. Kent, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E (President), in the Chair Published in "The Structural Engineer" Vol. XXXVIII, No.* 3, *pp.* 100-115.

By Type of Concrete

Reinforced	20%
Pre-stressed	5%
Plain	50%
Mortar	20%
Asbestos	3%

By Type of Purchaser

Precast (Factories)	20% ± 5%
* Ready Mix (1,000,000 cu. yd.)	5%
Site Mix and Mortar	75%

(* The figure quoted is for 1958)

These tables, he said, were interesting to a research unit. For example, the consumption of cement and concrete in houses, flats and offices accounted for a considerable proportion of the total. That was perhaps of less interest to the Cement and Concrete Association than to his own organization.

Drawing attention to the item covering ready-mixed concrete, he commented that its output had been doubling every 13 to 14 months over the last few years. So that this was a subject on which the support of a research programme was likely to be fruitful.

That led him to another matter, the influence of the cost of doing a job on the technological data which might be needed. Dr. Collins had shown diagrams of mix proportions, and a great deal of civil engineering research had been concerned with mixing, compaction, and so on, with an emphasis perhaps on economical and efficient use of cement in dry and fairly dry mixes. On the other hand, another research had shown that it was cheaper on a job to use more cement, but in a more fluid concrete. This influence of costs could lead to importance being attached to other kinds of technical data, for example, as to whether the more fluid concrete was also durable concrete.

The question of cost and its influence, he concluded, might come into research programmes on concrete a good deal more than it had formerly.

Mr. D. A. G. Reid (Member of Council), discussed an aspect of educational work connected with the Cement and Concrete Association, to which Dr. Collins had made reference.

Some years ago, he said, it was proposed that some attempt be made to provide courses of study in concrete practice for concrete workers; the proposal had caused some alarm in the industry. Nevertheless, with the strong support of the Cement and Concrete Association, courses of study were started.

Among the difficulties which arose were those of staffing, and in that connection not only were the Cement and Concrete Association in a position to help very materially with the provision of specialist lecturers, but they were also able to help very much with the training of members of technical college staffs who had some interest in and knowledge of concrete and whose knowledge could be increased immensely by a course or by other help from the Association. Furthermore, the Association had helped very considerably with the examinations.

Although development of the courses in concrete practice had not been very rapid, they had probably contributed quite usefully to improvement in concrete techniques. In this connection it was not without interest that Abram's original work was done in an organisation which might be regarded as a prototype of that of Dr. Collins, and one of the first reactions to that work was that some elementary training should be provided for the men in the lower grades who worked on the sites.

Asking about the work of the Cement and Concrete Association, he referred to the section of Dr. Collins' paper that dealt with the dissemination of information. It seemed to him that sooner or later the Association would have to enter the field of operational research, because a great deal of what they had found out would never be put over satisfactorily to industry until conditions on site were sufficiently well understood to permit new ideas to be instituted. We had some impression of the conditions under which concrete was produced and placed, but those impressions were fragmentary and, in considerable part, liable to some error. It was now very desirable that a more thorough knowledge should be obtained of the precise conditions in which concrete was produced and placed, and with that knowledge, improvements in technique could be achieved.

That sort of work was not easy and it was very time-consuming, but Mr. Reid thought it was work which the Cement and Concrete Association would have to add to their range of interest. As was pointed out in the paper, the effect of materials on concrete properties was less in practice than might have been expected from tests in the laboratories. That indicated the masking effect arising from incomplete understanding of site conditions.

Mr. Reid added his thanks to Dr. Collins for a most interesting paper.

Lt.-Colonel G. W. Kirkland, M.B.E. (Mil.) (Vice-President), recalled Dr. Collins' reference to the many advantages gained from automatic recording and the use of computers, and asked if in the near future they would have any effect on the numbers of laboratory staff employed.

Dr. P. W. Abeles (Member), said that he was alarmed at learning from Dr. Collins that strain readings could be taken automatically and dealt with by computers. Research engineers knew how important it was to compare strain readings with test assumptions so as to check the correctness of arrangement and in case of disagreements special investigations had to be introduced which sometimes resulted in new knowledge. All this would be lost if things were left to the computer and the human element were disregarded.

Dr. D. D. Matthews (Vice-President), supported the remarks made by the President in proposing the vote of thanks by drawing attention to what Dr. Collins had in fact done in the years during which he had been Director of Research.

We had heard, he said, of the true generosity of the cement industry in providing a first class site and buildings, and facilities in first class laboratories for concrete research. Many of us had known cases all over the world where large sums of money were distributed to scientists on a semi-political basis, and one was glad that Dr. Collins had mentioned it. Such research was as fashionable today as it was about 30 years ago. But, despite this excellent opportunity, they did not all do the work they were intended to do with a £1,000 or £2,000 machine; their work was very much down to earth, one felt it was being conducted by people who, although they produced a first class finish, were doing it because they were tidy workpeople and not merely because they wanted to spend the millions of dollars allocated to them.

One had been interested to hear Dr. Parker raise the point that the cheapest materials to buy were not necessarily the cheapest to use and that the use of the minimum amount of cement did not necessarily result in the production of a particularly cheap product.

Dealing with Mr. Reid's comment on the need for operational research, and his remark to the effect that none of us knew the conditions in which concrete was made on site, Dr. Matthews asked him to amplify that statement because it seemed capable of being misinterpreted.

Finally, he invited Dr. Collins to say a little more about the problem of the reinforcement around anchorages for prestressed concrete.

DR. A. R. LEE (Road Research Laboratory), added his expression of thanks and appreciation to Dr. Collins for the paper and said how much one admired the efforts of the Cement and Concrete Association in carrying out useful research. Certainly we should all like to see other industries concerned with civil engineering activities operating on a similar scale.

Commenting on Dr. Collins' remark that research was very much in favour at the moment, he said that at the time he was looking for a job one would find, if lucky, an advertisement somewhere in a corner of the back page of *The Times* indicating that research workers were required at a salary of about £150 a year. Nowadays, however, advertisements for research workers were put in the middle of a page and were quite often surrounded by a big 'picture frame.'

Speaking of co-operation in research, he said that the arrangements between the Cement and Concrete Association and the Department of Scientific and Industrial Research for research into concrete road problems had proved very successful. The time factor which was involved in all problems of durability, caused considerable difficulty particularly as it was not possible to simulate in a short time in the laboratory conditions which were operating on the normal road throughout a long period. However, repeated loading and tests for fatigue may well be useful methods for investigating the long-term problems.

The C. & C.A. was perhaps in a very advantageous position with regard to obtaining information on what was going on in the general field of concrete construction. They were in that position because they were selling a product and they were thereby able to keep their hands on the pulse of the highway engineering world a little more easily than other organisations; that was an additional reason for welcoming their co-operation.

In that same connection Dr. Lee mentioned the problem, on which Dr. Collins had touched, of lean concrete, or cement-bound granular material, as it was now called, something we did not know very much about, but which was being used on an increasingly large scale. It would be interesting to know what will happen to this material over a long period; should there be a large factor of safety on strength, what will be the effect of repeated strains; what is the risk of break-down of the concrete as a result of repeated movement at a crack?

In congratulating Dr. Collins on his achievements over the period covered by the paper, he added that it was particularly gratifying that such success should go to an old colleague from the Road Research Laboratory.

MR. E. A. SHAW, speaking as an engineer who had been at the receiving end of the research described in the paper, said how much he personally appreciated the information he had received from the C. & C.A. and how very helpful it had been.

He had found that research workers, at times, appeared loath to give a definite 'yes' or 'no,' and he felt it was because they were seeking information on basic things, they were dealing with the laws of nature and they realised how little we knew. Also he had noticed that they had a tendency to place perhaps more faith in their machines and instruments than in themselves.

He was most impressed to learn about the use of electronic computers and was fascinated to see the book of information on the design of skew bridges which Dr. Collins had shown and which had been produced completely by the machine. But one had noticed the touch of the research worker when he had said that the results were either all right or all wrong. Was it known which of these two alternatives was true?

MR. H. C. ADAMS (Ministry of Transport), after thanking the Institution for having invited him to the meeting, said that engineers were often criticised, sometimes not unjustly, for their inability to express their thoughts clearly on paper. But he wanted to say how much pleasure he had derived from reading Dr. Collins' paper; it was so lucid, so easy to understand. He would put it into the class of the papers presented some years ago by one of the Institution's Past Presidents, Mr. Gower Pimm; it was so much easier for engineers to assimilate information when it was set down so clearly. These remarks were personal to Dr. Collins, but to a considerable extent the paper reflected the clarity of thought which we had always found in the organisation he represented. That organisation was, he felt, in many ways unique, because its outlook was so broad. Most research organisations, probably of necessity, had to confine themselves to basic research and their activities had to remain fairly narrow.

The C. & C.A. not only carried out research, but also, as explained in the paper, they conducted courses; and he had reason to be grateful to the Association for the splendid work they had done through their bridge design courses, for they had helped his Department very much by the spread of knowledge to which they had contributed.

There were many other courses they conducted at their establishment, sometimes in the course of their research work. Further, they had kept their feet very firmly on the ground by keeping in touch with outside work. He could speak from experience of the very big contributions they had made in the field of bridge design and construction. His experience was that they had given his Department definite answers; when the Ministry had not known the answer to a problem, the Association had given a very definite answer from results which could be accepted with full confidence.

Giving examples of the contributions they had made, Mr. Adams referred to work on composite construction, i.e., the combination of precast prestressed concrete inverted 'T' beams with in situ concrete. He mentioned also their experimental work on transverse reinforcement as a contribution to the analysis of stresses imposed by the Ministry of Transport abnormal loading; their experimental work on torsion, using a model of the Medway bridge; on the Hammersmith flyover; on the reinforced concrete hinge in the Wentbridge viaduct on the Doncaster By-Pass; on surface finishes of concrete; and, most recently, their work in developing the standard beam, which he hoped we should all hear more about shortly.

Again, the Association had helped his Department and other highway authorities by visiting sites when

there had been mishaps and failures. These matters did not always get into the press, even the technical press. He could assure the meeting that the C. & C.A. had made very fine contributions.

None of these things, he added, were basic research ; they were applied research, yielding definite results, giving immediate help.

Speaking of the diagram in Fig. 7 of the paper, he said it recalled to his mind a period, nearly 40 years ago, in which over a number of years he had visited regularly the University of Illinois at a time when, amongst other things, they were busy with research on water/cement ratio. Although at that time we thought we knew quite a lot about water/cement ratio, it was interesting to see how, periodically, one more curtain had been drawn back ; one was led to contemplate how many curtains had been drawn back by the time the results illustrated in Fig. 7 were obtained.

Recalling Dr. Collins' reference to the testing of small specimens, Mr. Adams said that when a vast number of specimens of cylinders or cubes were tested we obviously had something by which to measure the scale effects. He asked how, when breaking new ground, the C. & C.A. were able to assess the scale effects between the small test specimens and the full size structure or member.

Next, he would like to know if there were any reliable information on the distribution of internal stresses from shrinkage with rich concrete in (say) the end blocks of post-tensioned beams and also in the halved joint between the free span and the cantilevered end of a cantilever and suspended span bridge, where there were concentrated stresses. He asked if knowledge was available on the contribution made by by shrinkage stresses.

Lastly, he referred to a statement in the Paper that the overall variability of field concrete could be expected to be less than that of the test cubes. He asked for a little more information on that.

Mr. A. Goldstein (Member), said that he had had the pleasure of working with the C. & C.A. on a number of occasions and had found that their efforts were of very great help to him. He had always been impressed, not only by the very excellent work carried out at Wexham, but also—amongst other things—by the informal and happy spirit existing amongst the staff at the Research Station. This greatly facilitated the ready interchange of information between the research team on the one hand and (in his case) the consultant's staff on the other.

During an early occasion Dr. Collins had pointed out a factor which had particularly impressed him. This was that if an engineer required to obtain certain answers by research work he would have to frame his questions very carefully indeed. They must be specific and directed at as few variables as possible. This really was the epitome of the old saying that if one asked a silly question one would get a silly answer. Engineers would be disappointed if they expected research to provide the panacea of all their problems.

The work of the research establishment clearly dealt with a difficult material—difficult because of all structural materials concrete was perhaps the one affected most by the vagaries of human nature. Dr. Collins' work had to cover a very wide field ranging from workmanship, i.e., research on site problems, to the most complex design problems.

An example of the former was the operational research mentioned before. This was particularly so in the case of ready mixed concretes of which there have been considerable developments in recent years. He was interested to hear the previous comments that the use of minimum quantities of cement was often not an economy at all and he agreed entirely. From his experience, however, it appeared that where ready mixed concrete was used then since different parties were responsible for providing concrete and for placing it, this view appeared not to be shared by those providing ready mixed concrete.

Referring to design work, one might have thought that the research work on this aspect would be simpler. However, design was often done in an extremely subjective manner and there were gaps where research had to catch up with design. An example of that had been referred to by Mr. Adams. This was the *ad hoc* experiment on the efficiency of a particular type of concrete hinge. Notwithstanding the extremely satisfactory results of tests it was established that a great deal of fundamental research work was required on this subject of hinges.

The same applied to prestressed concrete end blocks. It had been shown that methods used up to the present could lead to considerable underestimates of the stresses in the anchorage zones. The incidence of failures of end blocks, however, was very small indeed and he suspected that the reason for that was again that competent designers had not been content to rely on pure mathematics. In most cases the amount of reinforcement provided was considerably in excess of that which the present theories would indicate.

On a point of detail, Dr. Collins mentioned that the aggregate usually provided a limit on the strength of concrete from 12,000 to 15,000 p.s.i. Mr. Goldstein doubted this. He knew of considerable areas in England where the local aggregates set a limit much nearer the 8,000 p.s.i. If one required a concrete strength using that aggregate of 6,000 or 7,000 p.s.i. he had found that whilst in theory the aggregate should not provide any difficulty, in practice it did. The variability of seemingly identical cube tests was very great when using a design strength which was so near to the strength limitations caused by the aggregate. This often gave rise to an unacceptable number of test cube results which were below specification.

Mr. P. H. T. Gooding (Member), who claimed the unique distinction of being Dr. Collins' chief critic, congratulated him most heartily on a most interesting and clear paper. He also paid tribute to what was even more important, the work of Dr. Collins and his staff during the last ten years or more ; they had done remarkably good work. A particularly valuable part of it was that on the improved riding qualities of concrete roads.

Speaking of the reputation of the C. & C.A. Research, he said he knew personally that the work done at Wexham Springs was universally appreciated and had helped to build up the overall prestige of British structural engineering throughout the world.

Mr. S. B. Tietz (Associate-Member), made a plea in connection with the dissemination of information. Owing to the sheer volume of matter coming through, this was often filed away unread or inaccurately read in offices. It was often impossible to find time to read all of an article, and it would be very valuable if some index system could be devised, which could be printed on the article, and which would give in index form what the main contents were and what other aspects were dealt with.

This same index system could be widely published and might well form the basis for a more uniform and vastly improved filing system within engineers' offices. References could then be easily found as and when required.

At the C. & C.A. a great deal of reading was being done on research, often carried out abroad and published in languages not understood by the average engineer. The C. & C.A. would thus seem to be in a very strong position for helping devise such an index system, preferably not quite as detailed and therefore cumbersome as those existing.

If some engineer was then trying to find test results on say, torsion in beams, he could refer to the relevant index section of sub-section and obtain the necessary information both in his office and elsewhere.

Dr. A. Eisner Heublum asked whether the C. & C.A. had done any work on the resistance of concrete to gamma radiation, especially with regard to Civil Defence.

Dr. Collins, replying to the discussion, said he did not come to the meeting to listen to praise of the C. & C.A.; they did not learn anything from that, but they did learn from criticism. Nevertheless, he had felt very flattered by the kind things the speakers had said about the organization and by the friendly way in which the speakers had joined in the discussion.

He was grateful to Dr. Parker for his figures and for his remarks. Dr. Collins's feeling was that the reason why materials were the subject of more research than the methods of construction was that the materials were supplied by industries which had an identity, such as the cement industry, whereas construction work was carried out by a very broad and extremely numerous unorganized group. In almost every country in the world concrete was a favoured material for research. Maybe it was an occupational disease of cement makers to be interested in research, but he thought that an important reason was that cement was a more interesting material than the others. Whether this was so or not he could assure the meeting that it was a more difficult one.

Dealing with Dr. Parker's question on the subjects of research, he said it was clear that research effort should not be in proportion to the quantitities of materials used in practice, for if it were a large proportion of the effort would be devoted to mortar in brickwork and the making of concrete for the foundations of houses. The Association did research on the uses of concrete that seemed most important or required help in their development.

Dr. Collins thanked Mr. Reid for his remarks on education, which the Association regarded as very important; and also thanked him for his comments on operational research. He agreed with Mr. Reid on the need for research in this field but resources were at present too limited to allow much serious work to be done.

With reference to the remark of Colonel Kirkland on automation, he said that automatic recording apparatus did not eliminate research staff; it merely allowed them to do more work. He could also reassure Dr. Abeles; one did not expect to make an experiment, switch on the machine, then go away and come back after a while to find a report there. The automatic recording of results came when everything was working properly. The research worker was still required to understand the results; he used the machines merely to eliminate tedious repetition work and to eliminate human errors.

Dr. Collins said that Dr. Matthews had been his first teacher in the methods of research and he was very grateful to him for his remarks. In reply to Dr. Matthews' question he said that a report on the Association's work on stresses in the end regions of prestressed concrete members was soon to be published.

Several speakers had raised the question of the cement content in concrete. Dr. Collins agreed with what had been said and added that to the cost of placing one might add sometimes the cost of replacing ! He thought that operational research could play its part in presenting a true picture, but this would be a slow process and, in the meantime, accurate cost accounting on the site could make a useful contribution.

Concerning Dr. Lee's reference to co-operation with the Road Research Laboratory, Dr. Collins said that it had always been close; it was one of the few official relationships which the C. & C.A. had, and there was a very real reason for it. The R.R.L. had quite properly a monopoly of full-scale experiments on public roads, and it was right that the C. & C.A. should have a co-operative arrangement with them. It was a very happy arrangement, and he hoped that the R.R.L. obtained as much benefit from it as he and his staff had derived.

He could not answer Dr. Lee's question as to what would happen concerning lean concrete in the future, and he felt sure that Dr. Lee would agree that no one could give a proper answer at this stage.

In answer to Mr. Shaw's remarks, which it was obvious were not meant to be taken seriously, Dr. Collins said that the data on skew slabs had already been used for the design of about fifty bridges. The data were, in fact, quite correct; if they had not been so, the engineers using the information would have discovered the fact immediately.

He was grateful for Mr. Adams' remarks. Mr. Adams visited the research station frequently, and the Association had received much encouragement in its work not only from him personally, but from the whole of his staff at the Ministry of Transport. He had spoken at every course on bridge construction and often advised and guided the research workers engaged on bridge design.

Replying to his questions, Dr. Collins said that when small-scale tests were first begun in a new field the scale effects were not always known. Information had to be built up step by step using every opportunity of comparing results with full-scale tests.

The results of all model tests had to be interpreted with certain adjustments, but small-scale tests had worked remarkably well so far. Even in tests on the effects of explosions on structures, models gave a remarkably accurate picture of what would occur on the full-scale.

The request for information on the distribution of internal stresses due to shrinkage was not easy to meet. The question could probably never be answered directly, but only through separate lines of research on shrinkage, and the effect of the restraints that occur in actual structures. In the meantime, work was already in hand on the general phenomenon of shrinkage.

In answer to the question regarding the variability of concrete in a structure being less than that in test cubes, Dr. Collins said that the variation of small specimens was increased by variations in several factors that did not affect the large mass such as curing and testing. He considered that the cube test normally gave the worst possible view of the variability in the concrete except when the concrete in the structure was badly compacted.

A very interesting point was raised by Mr. Goldstein, for one would have expected that the variability of high strength concrete would be less than that of ordinary concrete. It might be that the aggregate itself was rather variable, and, therefore, in the high strength concrete the aggregate added to the variability of the concrete. But Dr. Collins would not like to say,

without further examination, that that was bound to be true.

The system Mr. Tietz had asked for was already in use in specialist libraries though whether it went far enough for Mr. Tietz he was not quite sure. In technical documentation highly complicated classification systems were not always satisfactory and no one system could be devised to suit all those requiring information. The best system seemed to be that of asking the specialist library for information as it was needed.

Coming to the last question put by Dr. Heublum, he said the C. & C.A. did some work, in co-operation with the building research and atomic energy research organizations, concerning the effects of gamma radiation on the properties of concrete. Some small cubes were in fact being irradiated in one of the piles at Harwell. Few results were yet available but Dr. Collins thought that the effects of the radiation would not be very great.

In conclusion, Dr. Collins thanked the meeting for the very kind way in which they had received the paper, and for the interesting discussion.

THE PRESIDENT, in closing the meeting, expressed the meeting's appreciation of the able manner in which Dr. Collins had replied to a most interesting discussion.

Written Discussion

MR. G. A. PITT asked from research on the properties of cement and concrete, what has been found to be the best treatment to improve the durability of exposed concrete surfaces and therefore the life of reinforced concrete structures, in particular, bridges?

He referred to a bridge in Kent, namely over the Medway at Maidstone, which could be guaranteed for perhaps 2,000 years, a state of affairs which should be very satisfying to Mr. Adams. It was built of four to five ton granite blocks and did not show any signs of deterioration after approximately 80 years of use. In the late twenties, the bridge was widened (work on which he was engaged) again using granite blocks.

There might appear to be an element of doubt about the durability of the surfaces of modern reinforced concrete bridges, particularly where located over railways exposed to sulphurous fumes from trains, and in other places where the air was badly polluted.

He asked what were the relative merits of protection by :—

(a) Silicone treatment, to reduce the soaking in of rainwater.

(b) Painting with chlorinated rubber based paints.

(c) Additives to the cement.

DR. C. B. WILBY (Associate-Member), commented that concrete control could be very difficult in practice. Sometimes the water added to a mix was measured by unreliable instruments and the water content of the aggregates was not measured. The water content of aggregates not protected from the weather could vary considerably in different parts of the stacks. On occasions when large concreting programmes used aggregates being delivered to the site during such programmes the water content could often be very high and variable in the aggregates of such deliveries, making the control of the water/cement ratio extremely difficult. Many sources of aggregates, which often made concrete of more than the specified strength, did not consistently comply with the British Standard recommendations ; as they depended greatly upon the grading of the natural supply. Also, when the aggregates were transported and poured into storage bins, etc., segregation occurred. It would seem that to exercise a very high standard of control it would be necessary to dry all aggregates and pay extra for aggregate suppliers to mix their products with aggregates from other sources to supply deficits of certain sizes, etc., to comply with the British Standard grading recommendations. To do this would be unnecessarily expensive in the many instances when one could easily obtain strengths satisfactory for the Code of Practice by relatively primitive and much more economical means. Providing good batching of the cement and aggregates could be ensured, he had always found that a good operator could produce a very consistent mix of concrete judging by 'feel' and by 'eye.' Also this method took into account humidity and temperature of the atmosphere. Even under laboratory conditions (where temperature and humidity had not been controlled) he had noticed considerable differences in the workability of mixes having exactly the same contents, due to variations in humidity and temperature.

Abrams law seemed to be extremely well known by almost everyone in the architectural and building professions. The necessity of good compaction did not seem to have received the same publicity, and sometimes lower water cement ratios were insisted upon than could be compacted satisfactorily by the amount and type of the equipment used on the contact. For many contracts the strength requirements were easily obtained and to sacrifice workability, which meant sacrifices in economy, compaction and surface finish, to obtain concrete far in excess of the strength requirements seemed to be bad practice. If workability was obtained with the addition of water, higher shrinkage resulted, and he had found wetting agents very useful for obtaining good workabilities with reasonably low water contents, and in one case of one product the field tests seemed to be more encouraging than the technical literature, possibly due to the inaccuracy of laboratory methods in imitating field workability.

He expressed interest in Dr. Collins' experiences concerning the shearing strength of beams with no web reinforcement. Certain tests showed[1 2] that the permissible shear stresses allowed by the current British Code of Practice could be far too high to give a reasonable load factor. British engineers had a great reputation for the reliability of their design. It was important constantly to upkeep this reputation and it would seem that if it was agreed that the permissible shear stresses of the British Code are too high, then no time should be lost in publicising British engineers to this effect. In this particular instance the Code of Practice of the American Concrete Institute was far more conservative and the writer had made other suggestions[1].

Perhaps Dr. Collins might give some more information as to the agreement between theory and the test results on the hyperbolic paraboloids.

Dr. Wilby congratulated Dr. Collins upon his paper and upon the valuable and excellent work he had done for the concrete industry over many years.

Reply to the Written Discussion

In reply to the written discussion, Dr. Collins says that he agrees with most of the views of Dr. Wilby on the subject of quality control. As was mentioned by Dr. Parker in the oral discussion, too much attention can easily be paid to economy in cement. While there is always a need for aggregates of reasonable and uniform

quality and for the mix proportions to be reasonably constant, the cost of obtaining very high standards in quality control may often be higher than that of making the mix a little richer. The same can be said about the uses of mixes of very low workability though it must be added that there are circumstances where rich or workable mixes are distinctly undesirable.

In answer to Dr. Wilby's enquiry about shear, Dr. Collins says that the Cement and Concrete Association has undertaken no research on shear up to the present time though it is planned to extend the present work on combined stresses in concrete to cover problems of shear at a later date. It is, therefore, not possible to give any information on the subject.

The question raised by Dr. Wilby regarding the agreement between theory and test results on hyperbolic paraboloids is one that is difficult to answer in a reply to a discussion. Some research is in progress in this field but it may be some time before a report can be published.

In reply to Mr. Pitt, Dr. Collins writes that the best method of obtaining durable concrete is in most circumstances simply that of making good concrete, compacting it properly and making sure that there is adequate cover over the reinforcement. The use of sulphate-resisting cement if there is any danger of sulphate attack is obviously a wise precaution but apart from this the effects of most surface treatments and additives are secondary compared with those of the proper mix design, quality control and compaction. Silicones definitely reduce the penetration of moisture and proper painting with chlorinated rubber paints can give a great measure of protection. Both, however, require renewing at intervals.

Little can be said about Mr. Pitt's remarks about the durability of bridges made with granite blocks except that however satisfactory a life of 2,000 years might or might not be to Mr. Adams, the task of his traffic engineering colleagues in Britain might now be very much easier if our old bridges had been less durable. Durability is not an absolute property; it has to be assessed statistically in relation to need, to first cost, to the possibility of deterioration and to the cost of repairs.

Bibliography

1. Wilby, C. B. *Journal of the American Concrete Institute.* v.29. No. 12. June 1958.
2. Subbiah, K. and Smith, R. B. L. *The Structural Engineer,* Vol. XXXVI No. 11. November 1958.

Book Reviews

Theory and Design in the First Machine Age, by Reyner Banham. (London : Architectural Press, 1960). 9 in. × 5½ in., 338 pp. 45s.

This rather forbidding title has been chosen for a volume containing a chronicle of events principally since 1910 which have led up to what is now generally termed the contemporary style in Architecture.

Mr. Banham traces the development of building design by the great experimenters of Nationalism, Futurism, Expressionism, Functionalism and many other 'isms' and explains in somewhat obtuse language how the various schools of thought in architectural design have influenced one another and themselves been influenced by the machine which in these last fifty years has so changed the habits of men and the methods of manufacturers.

The book is scholarly and well illustrated, but the somewhat stilted style makes it decidedly hard reading.

A.H.L.

Theorie und Berechnung der Stahlbrücken. (Theory and Calculation of Steel Bridges), by A. Hawranek and O. Steinhard. Berlin/Göttingen/Heidelberg, 1958. Springer-Verlag. 10 in. × 6½ in., 426 pp. plus xii, DM66.

The basic problems of the theory and calculation of steel bridges was generally dealt with some 30 to 40 years ago, and many books which were then published on this subject are still widely used today by engineers. However, with the development of new structural systems for bridges (such as the box girder, light steel floor systems, composite structures) in the last 15 years, new and more accurate methods of calculations have been evolved. The author has succeeded in this book in concisely bridging the gap between 'traditional' and modern theories.

The first four chapters deal generally with the basic theory of elasticity, plates, grids, and buckling of columns and plates, and gives practical methods of calculation which can be directly applied to design.

The fifth chapter discusses the deck systems of highway bridges. The author states that up to about 50 m. span a concrete deck reaches its economic limit but that for longer spans the light steel floor (orthotropic plate) is cheaper. Modern forms of plate systems are introduced including full details of the various methods of analysis based on the theories of grids and orthotropic plates, which are applicable to both steel and concrete decks.

Detailed information is given on the design of plate girders including box sections, and of continuous girders with varying moments of inertia. The effect of torsion on hollow rectangular shafts and the distribution of shear on sections with one or more intermediate walls are also discussed.

In dealing with truss girders, the calculation of secondary stresses is included, as well as the stability problems of portal frames and compression booms on open bridges.

The design of various types of arch bridge is next considered, including such aspects as the interaction between arch and floor system, and arch stability.

On suspension bridges, the author gives detailed information on the design of the earth-anchored type based on the deflection theory which takes the change of cable shape into account. Dynamic problems, particularly bending and torsional oscillations are treated in detail.

Finally, the author devotes a short chapter to the calculation of composite construction, including details of rigid and elastic structural connections.

Throughout the book, detailed numerical examples are given which greatly assist the reader in grasping the theoretical basis firmly. This book should prove of great value to those faced with the design of modern bridge structures.

B.F. and W.W.L.C.

Institution Notices and Proceedings

GENERAL MEETING

A General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1., on Thursday, 6th October, 1960, at 6 p.m., when the Presidential Address for the Session 1960-1961 was given by Lt-Colonel G. W. Kirkland, M.B.E.(Mil.), M.I.Struct.E., M.I.C.E.

Mr. L. E. Kent, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., the retiring President, was in the Chair.

After welcoming the guests, the Chairman presented Institution Awards for the past year.

Both the Bronze Sessional Medal and the Institution Branch Award were presented to Mr. Derek Bond for his paper, "Design, Model Analysis and Testing of an 83-ft. span Interconnected Portal Grillage."

The Drury Medal was presented to Mr. D. W. Hunt, winner of the Drury Medal Competition, 1959.

The Chairman then introduced Colonel Kirkland to the meeting. In some measure, he said, that had already been done in the current issue of the Journal, but that was done in two dimensions and it was now up to him to put the new President into '3-D' for them. Colonel Kirkland had been a great personal friend of his for many years, ever since the days in 1934 when for a short time they had worked together in the same office. He had had a distinguished career in engineering, both civilian and military. He was a member of more than one professional institution, but his heart was at 11, Upper Belgrave Street.

Members of the Institution had decided in their wisdom—and they were very wise—to elect him as their President for the forthcoming year. He brought to that office a considerable knowledge of the workings of the Institution and of the many committees which went to keep that working going on. He had had an experience which nobody else in the room had had or would have had, having been Chairman of the Committee which organised their 50th Anniversary Celebrations. They were fortunate that in these strenuous days they had found a man of this calibre for the job, to undergo the necessary steps which were an absolute prerequisite before he could approach the Chair, and for the next twelve months to dedicate himself—for that was what it was—to the Institution.

It was with somewhat mixed feelings that he, the Retiring President, removed his badge of office for the last time, feelings of relief and regret about which he could dilate, but for which this was neither the time nor the place.

The Retiring President then installed Lieutenant-Colonel G. W. Kirkland, M.B.E.(Mil.), M.I.Struct.E., M.I.C.E., as President of the Institution of Structural Engineers.

He said that there was no one whom he would rather invest with the Badge of Office and, on behalf of all the members of the Institution, he pledged the new President all the support he rightly deserved.

Thanking Mr. Kent for his remarks, The PRESIDENT said he felt certain that he had exaggerated in many ways. Knowing of Mr. Kent's great ability and efforts in the past year and the years which preceded it, when he had been through a similar field of service to the Institution, he regarded Mr. Kent as his pathfinder.

History for the Institution had been made that day, for Mr. Kent had presided over the first Council meeting to be held on the day of the inauguration of a new President. It was, therefore, his great pleasure to be able to inform members that the Council had passed a motion thanking Mr. Kent for his services to the Institution during his year of office and authorizing the award of a Past Presidential Badge.

Mr. Kent had made some very kind remarks referring to the pleasure despite the pain that he had felt about removing the Presidential Badge. There was no one from whom he would rather have received the Presidential Badge of Office and no one to whom he would rather hand a Past Presidential Badge than Mr. Kent.

It was as a token of the very great regard in which Mr. Kent's colleagues had held him throughout the year, and the even greater regard on its conclusion, which was even more important, that he presented him with the Past Presidential Badge to replace his badge of office. He hoped that Mr. Kent would enjoy wearing it as a relic of the very happy days which he had had as President and which he had given them while presiding over them.

In reply, Mr. Kent said that he was glad to be the first to address the new President. He was grateful for it having been agreed that a Past Presidential Badge should be awarded so early in the term of office of a new President, and he hoped that the practice would continue.

He had had a very happy year in office. The path had been considerably smoothed by the cordial welcome and efficient working which he had received from all branches and by the help and support which had been given by the Council, by members of the standing committees, and, of course, the permanent staff. To all of them he accorded his very deep thanks. He still had a few years in which to serve on the Council and during those years he would always be conscious of the very great honour which had been done him twelve months ago.

The President then delivered his Presidential Address.

MR. E. N. UNDERWOOD, proposing a vote of thanks, said that this was a privilege which had come like a bolt from the blue and he was glad that it had fallen in his direction. They had had a delightful talk on a most unusual topic. They had followed with keen interest the many nuances which the President had shown could be attached to the word equilibrium. He knew that he would be expressing the feelings of everybody when he thanked the President most sincerely for the wonderful talk which they had been given and wished him a very successful year of office.

Seconding the motion, MR. F. M. BOWEN, said that the President had given a most thought-provoking talk, but that was what they always expected of him. He had reminded them in his own way that an engineer was not a good engineer if he was content to consider only the purely technical aspects of their profession, He had also reminded them that, no matter how much they thought they did for the Institution, a little thought would reveal that they could all do more.

The President had said that it was difficult for him to follow his immediate predecessor and, no doubt, they would not expect him to achieve the extraordinary record that Mr. Kent had attained on the greens of the various branches, but it was fair to say that during his year of office, in one particular field not far from the Thames, he would attain greater heights than most people before him! He was sure that the President

knew that the greatest compliment which the speaker could pay him was to say, on behalf of all members, that they had every confidence that he would carry on the Institution at that same high level at which his predecessor had left it.

The motion was carried by acclamation.

In reply, The PRESIDENT said that he was sincerely grateful for what had been said. He had experimented on them and, since a presidency was not an office which he had experienced in any like body, he had not been sure that they would not come armed with missiles which might be thrown towards the platform were his words not of the right kind. However, knowing the status which the Presidential Chair had attained, thanks to its previous incumbents, it had been his prayer that they would not feel so inclined. He thanked them for hearing him out in what for the Institution had been an unusual subject.

The proceedings were terminated.

ORDINARY GENERAL MEETING

An Ordinary General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 27th October, 1960, at 5.55 p.m. Lt.-Colonel G. W. Kirkland, M.B.E.(Mil.), M.I.Struct.E., M.I.C.E. (President), in the Chair.

The Minutes of the Ordinary General Meetings held on the 26th May and 25th June, as published in the Journal, were taken as read, were confirmed and signed.

The following members were elected in accordance with the Bye-Laws. Will members kindly note that the elections, as tabulated below, should be referred to when consulting the Year Book for evidence of membership.

GRADUATES

AYANLAJA, Thomas Omodele Modupe, of Birmingham.
BAINES, Roy Taylor, of Dunedin, New Zealand.
BROWN, Roy Charles, of Dorking, Surrey.
CHADWICK, Raymond Joseph, of Bury, Lancs.
CLEWORTH, Graham, of Westhoughton, Lancs.
DALVI, Prabhakar Laxmanrao, of London.
DODHIA, Sobhagchand Lalji, B.E., of London.
GOPALAKRISHNAN, Narayana, B.Sc., of Johore, Malaya.
HARDY, Bernard James, of Greenford, Middlesex.
KIELY, Patrick Denis, of London.
MODY, Anilkumar Ochhavlal, of Ahmedabad, India.
OLIVER, Brian Vernon, of Bulawayo, Southern Rhodesia.
POWELL, Malcolm Maurice, of London.
ROBERTS, Charles Albert, of London.
SHETYE, Gajanan Anant, of Cardiff.
STRYDOM, Charles Johannes, of Cape Town, South Africa.
VIDAL, Selwyn Francis Fitzpatrick, of London.
WATSON, Nigel Anthony, of Rottingdean, Sussex.
WINDSOR, Keith Charles, of Warlingham, Surrey.

ASSOCIATE-MEMBERS

BIELOUS, Jaroslaw Wiktor, A.M.I.C.E., of Ashford, Middlesex.
BLAIN, Derek Peers, B.Sc., of Sale, Cheshire.
BURBAGE, Roy Saunt, of Stratford-upon-Avon, Warwicks.
CARCAS, Ronald Stanley, of Bath, Somerset.
CHMIEL, Kazimierz Otton, B.Sc., of Lichfield, Staffs.
CORLETT, Derek Henry, of Cwmbran, Mon.
DURRANT, Leslie Dennis, of Ipswich, Suffolk.
GHAUS, Mian Ghulam, of Sargodha, West Pakistan.
GOLINSKI, Jerzy, of London.
GOLLINS, Donald Edwin, of Ferndown, Dorset.
GRAY, Gordon Maxwell, of Salisbury, Southern Rhodesia.
HENFREY, Douglas, B.Sc., A.M.I.C.E., of Stockport, Cheshire.
JANI, Asmatullah of London.
JENKINS, Capt. Eric Graely, R.E., B.Sc.(Eng.), of London.
JOHNSON, Capt. John Richard, R.E., B.Sc., of Sutton, Surrey.
LANGFORD, Joseph Kenneth, of Woodsetton, Worcs.
LAWSON, Francis Noel, of Middlesbrough.
MOON, Michael Roy, of London.
PARSONS, Arthur Robert, of London.
ROOT, Alan James, of Old Coulsdon, Surrey.
ROY, Amal Chandra, of London.
SELKIRK, Arthur Thomas, of Cape Town, South Africa.
SMITH, Bryan Stafford, B.Sc., of Bristol.
SPRUCE, Alan Hugh, of Watford, Herts.
VAUGHAN, Colin, of Wirral, Cheshire.
WINKLER, Felix Gershon, of London.

TRANSFERS

Students to Graduates

AGRAWAL, Ramesh Chandra, of Bombay, India.
BAMFIELD, Eric Michael, of Durban, South Africa.
EGAN, Charles Henry Joseph Anthony, of Dublin, Ireland.
ERASMUS, Jan Hendrick, of Bolton, Lancs.
FEARNLEY, John, of Leigh, Lancs.
FITZPATRICK, John Anthony, of London.
HODGSON, William, of Cape Town, South Africa.
JOHNSON, James Charles, of Wellington, New Zealand.
JONES, William Leslie, of Cwmbran, Mon.
KWONG TAK CHEONG, of Kowloon, Hong Kong.
MAGUIRE, Robert, of Belfast, Northern Ireland.
MAK SECK HONG, of Singapore.
MARRIOTT, Kenneth, of Alfreton, Derbyshire.
MISRA, Ashok Kumar, of Gorakhpur, U.P., India.
NASIM, Syed Mohamed, of London.
O'HANLON, Terence Patrick, of Liverpool.
PAGE, David George, of Cape Town, South Africa.
PATEL, Shankarbhai Sendhabhai, of North Gujarat, India.
PATKAR, Bhalchandra Gajanan, of Bombay, India.
PORTER, Michael John, of Reading, Berks.
SHENOLIKAR, Gurunath Madhav, B.E. (Civil) Hons. of Bombay, India.
SIN TOH CHENG, of Singapore.
SKILTON, David Alan, of Auckland, New Zealand.

Student to Associate-Member

FUDGE, Peter Herbert, of Montreal, Canada.

Graduates to Associate-Members

BARRETT, Brian Albert, A.M.I.C.E., of Crawley, Sussex.
BAKER, Peter John, of Streetly, Staffs.
BARNARD, John Desmond Nico, B.Sc., A.M.I.C.E., of Durban, South Africa.
BATES, Peter John, of London.
BLAKE, Ronald James, of Harrow, Middlesex.
BRADLEY, John, of Farnborough, Hants.
BRINDLEY, John Hall, of Hollywood, Nr. Birmingham.
BROWN, Donald Robert, of Wellington, New Zealand.
BUTLER, Brynmor, of Bridgend, Glamorgan, South Wales.
CANNON, John Charles, M.A., of Knutsford, Cheshire.

COOPER, Harold Kenneth, B.Sc., of Benoni, Transvaal, South Africa.
CUFFE, Terence Neil, of Johannesburg, South Africa.
DINES, Edward Lawrence, of Old Bexley, Kent.
DREWETT, George Iain Hay, of Edmonton, Alberta, Canada.
EDWARDS, Paul Harper Dickinson, A.M.I.C.E., of London, Ontario, Canada.
FOULGER, Francis Charles Christopher, of London.
GARNER, Graham, of Codsall, Staffs.
GILL, John David, of London.
GRIFFIN, Ernest John of Hounslow, Middlesex.
HARRIS, Colin Frederick, of Uganda, British East Africa.
HILSON, Barry Oliver, B.Sc., of Brighton, Sussex.
HOLLAND, Philip Garth, of Spondon, Derby.
HOLLAND, Robert, of Thornton Heath, Surrey.
HOUGHTON, Stanley, of Wirral, Cheshire.
HURST, Bertram Lawrence, B.Sc., of London.
JENKINS, David Ernest, B.Sc.(Eng.), Ph.D., of Fownhope, Nr. Hereford.
JOHNSON, Peter Frederick, of Woodford Green, Essex.
JUDD, Henry Courtenay, of Cardiff.
LEE, David John, B.Sc.Tech., A.M.I.C.E., of London.
MCDONALD, John, of Cardiff.
MAKIN, Douglas William, of London.
MAYNARD, Arthur Leslie, of Ilford, Essex.
MINETT, Peter Burne, of Farnborough, Hants.
MUKHOPADHYAY, Amaresh, B.E., of London.
PHILLIPS, Lionel, B.Sc., A.M.I.C.E., of Bristol.
POVEY, Anthony Thomas, of Mitcham, Surrey.
REDDIN, Peter John, of Ewell, Surrey.
SCHALLER, Brian George Allen, of Salisbury, Southern Rhodesia.
SCOTT-WHITE, Raymond, B.Sc.(Eng.), of Sanderstead, Surrey.
SLACK, John Hartley, of Coventry.
STEDMAN, Michael John, B.Eng., of Worcester Park, Surrey.
STUART, Peter Leslie, of Enfield, Middlesex.
SUTTON, Noel William, of Lower Hutt, New Zealand.
UPTON, David John, of Rickmansworth, Herts.
WALSH, Malachy, B.E., A.M.I.C.E.I., of Cork, Ireland.
WARD, Charles Henry, of London.
WATKINS, Gerald Richard, of Farnborough, Hants.
WEBB, Ian Robin, of London.
WILLIAMS, John Hugh Hammerton, of London.
WILTSHIRE, Dennis Edward, of Worcester Park, Surrey.
YOUNG, Richard Charles, of Edinburgh.

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, 8th December, 1960

Ordinary Meeting at 6 p.m., when Mr. C. A. C. Davies, M.I.C.E., will read a paper on "The Structural Engineer in the Coal Industry."

Thursday, 15th December, 1960

Ordinary General Meeting at 5 p.m. for the election of members.

Thursday, 12th January, 1961

Ordinary Meeting at 6 p.m., when Mr. A. Short, M.Sc., J.P., M.I.Struct.E., and Mr. W. Kinniburgh, F.R.I.C., will give a paper on "The Structural Use of Aerated Concrete."

Thursday, 26th January, 1961

Ordinary General Meeting for the election of members, 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when Mr. P. B. Edwards, A.M.I.Struct.E., and Mr. R. B. Rigg will give a paper on "The Design and Construction of Extension to British European Airways Engineering Base at London Airport."

Thursday, 9th February, 1961

Ordinary Meeting at 6 p.m., when Mr. J. B. Dwight, M.A., M.Sc., A.M.I.Mech.E., will give a paper entitled "Aluminium Strut Design."

Thursday, 23rd February, 1961

Ordinary General Meeting for the election of members, 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when Professor S. R. Sparkes, M.Sc., Ph.D., M.I.Struct.E., M.I.C.E. (Member of Council), and Dr. J. C. Chapman will give a paper entitled "Model Methods, with particular reference to Three Recent Applications in the Field of Steel, Composite and Concrete Construction."

Members wishing to bring guests to the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

Graduates and Students of the Institution are reminded that these meetings are open to them and they are welcome both to attend the meetings and take part in the discussion on the papers presented.

EXAMINATIONS, JANUARY, 1961

The Examinations of the Institution will next be held in the United Kingdom and overseas on the 10th and 11th January, 1961 (Graduateship), and the 12th and 13th January, 1961 (Associate-Membership).

THE INSTITUTION OF ROYAL ENGINEERS

The Council have made the following facilities available to members of the Institution of Royal Engineers :—

(a) they will be welcome to attend as visitors all ordinary meetings of the Institution of Structural Engineers at Headquarters, Branches and Sections throughout the world ;
(b) copies of THE STRUCTURAL ENGINEER will be supplied at cost to all members of the Institution of Royal Engineers who may be interested ;
(c) the use of the library.

Branch Notices

LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged :

Thursday, 8th December, 1960

Mr. J. K. Anderson, M.A., M.I.C.E., on "The Runcorne/Widnes Bridge Project."

Tuesday, 17th January, 1961

"Vibration Problems in Relation to Foundation Design and Construction," by Mr. J. H. A. Crockett, B.Sc., A.M.I.Struct.E., A.M.I.C.E.

Friday, 3rd February, 1961

Annual Dinner Dance in the Derby Suite, Midland Hotel, Manchester.

Wednesday, 15th February, 1961

Joint Meeting with the Institute of Welding. "The Influence of Welding on Structural Design," by Mr. W. Bates, M.I.Struct.E. (Past Chairman).

Unless otherwise stated, all meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m. Light refreshments will be served from 5.45 p.m.

MERSEYSIDE PANEL

The following meetings have been arranged :

Monday, 23rd January, 1961

Prestressed Concrete and C.P. 115 by Mr. A. J. Harris, B.Sc.(Eng.), M.I.C.E., M.Cons.E.

At Liverpool University in the New Civil Engineering Building, Brownlow Hill.

Tuesday, 21st February, 1961

Junior Members' Evening.

At the College of Building, Clarence Street, Liverpool.

All Meetings will commence at 6.30 p.m. and will be preceded by light refreshments from 5.30 p.m.

Joint Hon. Secretaries : Wm. S. Watts, M.I.Struct.E., A.M.I.C.E., 11, Newchurch Lane, Culcheth, Nr. Warrington, Lancs., and M. D. Woods, A.M.I.Struct.E., 8, Dennison Road, Cheadle Hulme, Cheshire.

MIDLAND COUNTIES BRANCH

The following meetings have been arranged :

Wednesday, 7th December, 1960

" Concepts of Structural Safety " by Professor R. C. Coates, Ph.D., B.Sc., M.I.C.E., Professor of Civil Engineering, Nottingham University. Joint Meeting with the East Midlands Local Association of the Institution of Civil Engineers.

At the East Midlands Electricity Board Showrooms, Irongate, Derby, at 6.15 p.m. Tea will be served from 5.45 p.m.

Friday, 27th January, 1961

" The Structural Engineer in the Field of Atomic Energy," by Mr. T. C. Waters, M.I.Struct.E. (Member of Council), Chief Structural Engineer, United Kingdom Atomic Energy Authority, Warrington. Joint Meeting with the Institute of Welding, Birmingham Branch.

Friday, 24th February, 1961

" Computers and Structural Design—The present position and Future Trends," by Mr. R. E. Rowe, M.A., M.I.C.E., Cement and Concrete Association.

Unless otherwise stated all meetings will be held at the Byng Kenrick Suite, College of Advanced Technology, Gosta Green, Birmingham, 6, at 6.30 p.m. Tea will be served from 5.45 p.m.

Hon. Secretary : S. M. Cooper, A.M.I.Struct.E., " Applegarth," Hyperion Road, Stourton, Nr. Stourbridge, Worcestershire.

GRADUATES' AND STUDENTS' SECTION

Friday, 2nd December, 1960

" Structural Engineering in the U.S.A." by Mr. J. W. Fortey, B.Sc., M.S., A.I.Mun.E., A.M.I.Struct.E., recently lecturer at the University of Texas. This meeting will be of general interest, and will be open to wives and friends.

Friday, 6th January, 1961

" Precast Concrete Frame Construction " by Mr. Bryan E. Griffin, A.M.I.Struct.E., of Concrete Limited.

Friday, 20th January, 1961

Fourth Annual Buffet Dance, at the Station Hotel, Dudley.

Friday, 3rd February, 1961

" Structural Engineering in the Construction of the Inner Ring Road " by Mr. S. G. Piggot, Principal Engineering Assistant in Birmingham Public Works Structural Department.

Unless otherwise stated, all meetings will be held at the Engineering Centre, Stephenson Place, Birmingham, at 6.30 p.m. Tea will be served from 6 p.m.

Hon. Secretary : H. T. Dodd, Shepherd's Cottage, Grove Lane, Wishaw, Sutton Coldfield, Warwickshire.

NORTHERN COUNTIES BRANCH

The following meetings have been arranged :

Tuesday, 6th December, 1960

At the City Hall, Newcastle, 7 p.m. Joint Management Committee Meeting. " Man and Moloch," by Mr. J. R. T. Gibson Jarvie, of the United Dominions Trust.

Tuesday, 6th December, 1960

At Middlesbrough. " Clifton Bridge, Nottingham " by Messrs. J. C. Adamson, B.Sc., A.M.I.C.E., A.M.I.Mun.E., and A. Goldstein, B.Sc.(Eng.), A.M.I.Struct.E., A.M.I.C.E.

Wednesday, 7th December, 1960

The above paper will be repeated at the Neville Hall, Newcastle.

Tuesday, 3rd January, 1961

At Middlesbrough. Students' and Graduates' Meeting. " Design of Welded Plate Girders " by Mr. O. A. Kerensky, B.Sc., M.I.Struct.E., M.I.C.E.

Wednesday, 4th January, 1961

At Newcastle. Joint Meeting with the Northern Architectural Association. " Value for Money in Building " by Mr. E. S. Benson, M.B.E., M.A., F.R.I.B.A.

Wednesday, 1st February, 1961

At Newcastle. Students' and Graduates' Meeting. Address by Mr. W. E. J. Budgen, B.Sc., M.I.Struct.E., M.I.C.E.

Tuesday, 7th February, 1961

At Middlesbrough. Joint Meeting with the Northern Counties Association of the Institution of Civil Engineers, 5.45 p.m. for 6.15 p.m. " The Channel Crossing—Bridge or Tunnel," by Mr. J. F. Pain, M.C., B.Sc.(Eng.), M.I.C.E.

Unless otherwise stated, meetings in Newcastle will be held at the Neville Hall, and those in Middlesbrough at the Cleveland Scientific and Technical Institution, and will commence at 6.30 p.m. preceded by a buffet tea at 6 p.m.

Hon. Secretary : P. D. Newton, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., Messrs. S. Cussons and Partners, 112, Borough Road, Middlesbrough.

NORTHERN IRELAND BRANCH

The following meetings have been arranged :

Tuesday, 6th December, 1960

" Lift Slab Construction " by Mr. F. R. Benson. Joint Meeting with the Northern Ireland Association of the Institution of Civil Engineers.

Tuesday, 3rd January, 1961

To be arranged.

Tuesday, 7th February, 1961

" Concrete Bridge Design " by Mr. I. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E.

Meetings will be held in the Civil Engineering Department, David Keir Building, Queen's University, Belfast, at 6.30 p.m., unless otherwise notified. Tea will be served from 5.45 p.m. to 6.30 p.m.

Hon. Secretary : L. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast, 5.

SCOTTISH BRANCH

The following meetings have been arranged :

Wednesday, 7th December, 1960

Meeting at Edinburgh—see Edinburgh Section.

Tuesday, 13th December, 1960

" The Use of Timber as a Structural Medium " by Mr. J. H. Jaap, A.M.I.Struct.E.

Tuesday, 24th January, 1961

" The Provisions of the Revised British Standard for the Use of Structural Steel in Building—B.S. 449/1959 " by Mr. Walter C. Andrews, O.B.E., M.I.Struct.E., M.I.C.E. (Past President).

Wednesday, 25th January, 1961

Meeting at Edinburgh—see Edinburgh Section.

Friday, 17th February, 1961

Joint Meeting with the Glasgow and West of Scotland Association of the Institution of Civil Engineers. "The Development of Nuclear Power in the United Kingdom" by Mr. T. C. Waters, M.I.Struct.E. (Member of Council, Past Chairman, Lancashire and Cheshire Branch).

Unless otherwise stated, meetings will be held at The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, commencing at 7 p.m.

EDINBURGH SECTION

Wednesday, 7th December, 1960

Joint Meeting with the Edinburgh and East of Scotland Association of the Institution of Civil Engineers. "Zambesi Hydro Electric Development at Kariba—First Stage" by Mr. T. A. L. Paton, C.M.G., B.Sc., M.I.Struct.E., M.I.C.E., and Mr. C. I. Blackburn. At the North British Hotel, Edinburgh, 6 p.m.

Wednesday, 25th January, 1961

"The Provisions of the Revised British Standard for the Use of Structural Steel in Building—B.S. 449/1959" by Mr. Walter C. Andrews, O.B.E., M.I.Struct.E., M.I.C.E. (Past President), at the Heriot-Watt College, Edinburgh, 6.30 p.m.

Hon. Secretary: W. Shearer Smith, M.I.Struct.E., A.M.I.C.E., c/o The Royal College of Science and Technology, George Street, Glasgow, C.1.

SOUTHERN BRANCH

Hon. Secretary: A. P. K. Tate, B.Sc., A.M.I.Struct.E., Department of Civil Engineering, The University, Southampton.

SOUTH-WESTERN COUNTIES SECTION

The Opening Meeting in Plymouth was held on the 8th November, 1960, when Mr. A. N. Perkins, M.I.Struct.E., gave his Chairman's Address "Constructional Achievements Overseas."

The following meetings have been arranged:

Wednesday, 7th December, 1960

"Tamar Suspension Bridge," Joint Meeting with the Institution of Civil Engineers and the Institution of Municipal Engineers, at 10.30 a.m. Talk to be given by a member of the staff of Messrs. Mott, Hay and Anderson, Consulting Engineers, at the Scott Memorial Theatre, Plymouth, followed by luncheon and a site visit at 2 p.m.

Friday, 27th January, 1961

Paper to be read by Mr. H. J. Scoles, L.R.I.B.A., M.I.Struct.E., a member of the Section Committee, at The Victoria Hotel, Torquay. Title of the paper to be advised in due course. Tea at 5.30, followed by meeting at 6 p.m.

Friday, 24th February, 1961

Joint Meeting with the Institution of Civil Engineers. "The Choice of Protective Schemes for Structural Steelwork," by Mr. F. Fancutt (Assistant Director of Research B.T.C.) and Mr. J. C. Hudson (Head of Corrosion Section, British Iron and Steel Research Association) at the Duke of Cornwall Hotel, Plymouth. Tea at 5.30, meeting at 6 p.m.

Hon. Secretary: C. J. Woodrow, J.P. "Elstow," Hartley Park Villas, Mannamead, Plymouth, Devon.

WALES AND MONMOUTHSHIRE BRANCH

Tuesday, 6th December, 1960

Joint Meeting with the South Wales Institute of Architects, Western Branch. "Brazil, Venezuela and Mexico," by Mr. Alex J. Gordon, Dip.Arch., A.R.I.B.A., at Swansea.

Wednesday, 1st February, 1961

Joint Meeting with the South Wales Institute of Architects, Western Branch. "The Planning and Design of the Central Market, Swansea," by Messrs. Howel Menders, L.R.I.B.A., and J. M. Burke, M.A., A.M.I.Struct.E., at Swansea.

Thursday, 2nd February, 1961

Joint Meeting with the Institution of Civil Engineers and the Institution of Municipal Engineers. "Multi-Storey Car Parks," by Mr. E. C. Roberts, M.Eng., M.I.C.E., M.I.Mun.E., at Cardiff.

Tuesday, 21st February, 1961

"Economics of Framed Structures" by L. R. Creasy, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., at Cardiff.

Meetings at Cardiff will be held at the South Wales Institute of Engineers, Park Place, and will commence at 6.30 p.m.

Meetings at Swansea will be held at the Mackworth Hotel, High Street, and will commence at 6.30 p.m.

Hon. Secretary: W. D. Hollyman, A.M.I.Struct.E., 41, Greenfield Avenue, Dinas Powis, Glamorgan.

WESTERN COUNTIES BRANCH

The following meetings have been arranged:

Friday, 2nd December, 1960

"The Characteristics of Friction Grip Bolt Joints," by Dr. M. S. G. Cullimore.

Friday, 6th January, 1961

Joint Meeting with the Reinforced Concrete Association. "Lift-Slab Design and Construction," by Mr. F. R. Benson, B.Sc.(Eng.), A.M.I.C.E.

Friday, 3rd February, 1961

Joint Meeting with the Bristol and Somerset Society of Architects. The meeting will be held as a Forum, the Panel answering questions submitted by members.

Panel:

Architect: Mr. M. J. Hislop, A.R.I.B.A., F.R.S.A.
Quantity Surveyor: Mr. R. H. Mildred, F.R.I.C.S., F.I.Arb.
Contractor: Mr. R. C. Lorraine, B.Sc.(Eng.).
Engineer: Mr. Lewis E. Kent, B.Sc., M.I.Struct.E., M.I.C.E. (Past President).
Question Master: The Chairman, Clifford E. Saunders, M.I.Struct.E.

Tuesday, 14th February, 1961

Annual Dinner and Dance to be held at the Ashton Court Country Club, Failand, Bristol, from 7.30 p.m. to 1 a.m.

All meetings to be held in the Small Lecture Theatre of the University Engineering Laboratories, University Walk, Bristol, 8, at 6 p.m., preceded by tea at 5.30 p.m.

Hon. Secretary: A. C. Hughes, M.Eng., A.M.I.Struct.E., A.M.I.C.E., 21, Great Brockeridge, Bristol, 9.

THE YORKSHIRE BRANCH

The following meetings have been arranged:

Wednesday, 7th December, 1960

"Recent Prestressed Concrete Work in North America and the Commonwealth," by Mr. Donovan H. Lee, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., M.I.Mech.E. (Hon. Curator).

Wednesday, 14th December, 1960

At Leeds. "The Use of the Electronic Computer in Structural Engineering," by Dr. E. Lightfoot, M.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E.

Wednesday, 18th January, 1961

At Leeds. "Research for the Concrete Industry," by Dr. A. R. Collins, M.B.E., M.I.Struct.E., M.I.C.E. (Member of Council).

Wednesday, 1st February, 1961

Details to be announced.

Wednesday, 15th February, 1961

At Leeds. "Bridge Construction," by Mr. E. R. Bowers, Works Superintendent, Dorman Long Ltd.

Meetings at Leeds will be held at the Metropole Hotel, King Street, unless otherwise stated, and meetings at Sheffield at the Royal Victoria Hotel. Meetings will commence at 6.30 p.m. preceded by a buffet tea at 6.15 p.m.

Hon. Secretary: W. B. Stock, A.M.I.Struct.E., 34, Hobart Road, Dewsbury, Yorks.

UNION OF SOUTH AFRICA BRANCH

Hon. Secretary: E. B. Kretzchmar, A.M.I.Struct.E., P.O. Box 3306, Johannesburg, South Africa.

Natal Section Hon. Secretary: J. C. Panton, A.M.I.Struct.E., A.M.I.C.E., c/o Dorman Long (Africa) Ltd., P.O. Box 932, Durban.

Cape Section Hon. Secretary: R. F. Norris, A.M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

EAST AFRICAN SECTION

Hon. Secretary: K. C. Davey, A.M.I.Struct.E., P.O. Box 30079, Nairobi, Kenya.

SINGAPORE AND FEDERATION OF MALAYA SECTION

Hon. Secretary: W. N. Cursiter, B.Sc., A.M.I.Struct.E., A.M.I.C.E., c/o Redpath, Brown & Co. Ltd., P.O. Box 648, Singapore.

NIGERIAN SECTION

Hon. Secretary: A. Brimer, A.M.I.Struct.E., Brimer, Andrews and Nachshen, Private Mail Bag, 2295, Lagos, Nigeria.

ADDITIONS TO THE LIBRARY

American Society of Civil Engineers Transactions, Vol. 124, 1959. New York, 1959.

Axelrad, D. R. *Strength of Materials for Engineers.* London, 1959. Presented by Mr. D. T. Williams.

Department of Scientific and Industrial Research, Industrial Research and Development Expenditure, 1958. London, 1960.

Dutron, P. & Huberty, J. *Resurfacing and Widening Old Concrete Carriageways with Concrete.* London, C. & C. A. Library Translation No. 88.

Fire Protection Association Booklet No. 38. *Good Practice in the Fire Protection of Buildings.* London, 1959.

Gill, H. R. *Concrete Formwork Designer's Handbook.* London, 1960.

Institution of Mechanical Engineers' Proceedings, 1958, Vol. 172. London, 1960.

Jacobsen, Aas. *Die Berechnung der Zylinderschalen.* Berlin/Göttingen/Heidelberg, 1958. Presented by Dr. K. Hajnal-Konyi.

Prager, W. *An Introduction to Plasticity.* Reading, Massachusetts and London, 1959. Presented by Mr. Abu Bakr Ali Rida.

Robinson, K. E. *The Behaviour of Simply Supported Skew Bridge Slabs under Concentrated Loads.* London. Cement and Concrete Association Research Report 8, 1960.

Sewell, F. E. A. B. & Woolmer, S. C. *The Work of the Singapore Improvement Trust*, 1958. Singapore, 1960.

Timber Development Association. Timber Roofs for Factory Buildings and the Thermal Insulation (Industrial Buildings) Acts, 1957. London, 1960.

Wright, D. T. & Green, R. *Human Sensitivity to Vibration.* Ontario, Canada. Queen's University Report No. 7, 1959.

The following papers have been added to the Library:

The Relationship between Contractors and their Clients, by W. H. G. Durose (late Member).

Prestressed Concrete Works in Northern Ireland, by J. G. Berry (Member) and W. A. Toner.

SOME RECENT PUBLICATIONS OF INTEREST TO STRUCTURAL ENGINEERS

House of Commons Bills Session 1959-60—

(102) Corporate Bodies' Contracts. As amended by Standing Committee C. 6d.

(110) *Pier and Harbour Provisional Order.* (Fowey). 8d.

(111) *Pier and Harbour Provisional Order.* Yarmouth (Isle of Wight). 6d.

(114) *Road Traffic and Roads Improvement.* As amended by Standing Committee D. 1s. 11d.

Command Papers—

(1049) *Department of Scientific and Industrial Research.* Report of the Research Council, 1959. 4s. 10d.

(1053) *Copy of a Treasury Minute dated May* 13, 1960, concerning a Proposal by the Iron and Steel Holding and Realisation Agency to sell its Holding of Securities in J. J. Habershon & Sons, Limited. 5d.

Department of Scientific and Industrial Research—

Building Research Station Digest No. 134. May, 1960. Questions and Answers on Underground Drainage. (72-22-1-34). 6d. Quantity rates available on application.

Forest Products Research Laboratory Leaflet No. 43. Prevention of Lyctus Attack in Sawn Hardwoods by Use of 'Contact' Insecticides. Revised Jan. 1960. (47-214-43-60). 8d.

Road Research—

Road Note No. 27. Instructions for using the Portable Skid-resistance Tester. (47-141-27). 1s. 11d.

Technical Paper No. 46. London-Birmingham Motorway Traffic and Economics. Part 1. Traffic Investigation. (By T. M. Coburn B.Sc.); Part 2. Economic Assessment. (By M. E. Beesley, Ph.D., B.Com. and D. J. Reynolds, B.Sc. (Econ.). October, 1959. 47-110-46). 6s.

Treasury—

Public Income and Expenditure, 1959-60. Account of the Public Income and Expenditure of the United Kingdom, 1959-60, with the Balances in the Exchequer on April 1, 1959; the Receipts and Payments (not being Income and Expenditure) in the year ended March 31, 1960; and the Balances in the Exchequer on that Day. (H.C. 181). 8d.

Non-Parliamentary—

Impact of Science on Society. Quarterly. 9s. 6d.

House of Lords Papers and Bills, June, 1960—

(112) *Clean Rivers (Estuaries and Tidal Waters).* Bill. As amended in Committee. 11d.

(113) *Offices Bill.* Amendments to be moved on 3rd Reading: (113a) 5d. (113b) 5d. Marshalled List of Amendments (113) 5d. (114). Road Traffic and Road Improvement Bill. 2s. 2d. Amendments to be moved in Committee: (114a) 5d.; (114b), 5d.; (114c), 6d.; (114d), 5d.; (114e), 5d.

House of Commons Papers—

216. *Ancient Monuments Boards* for England, Scotland and Wales. Sixth Annual Reports, 1959. 1s. 8d.

217. *Annual Report of the Iron and Steel Board*, 1959. 5s. 4d.

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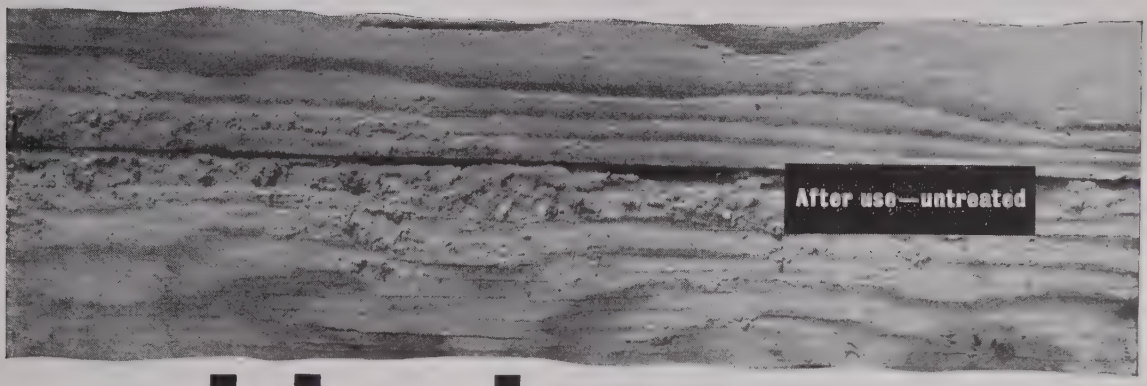

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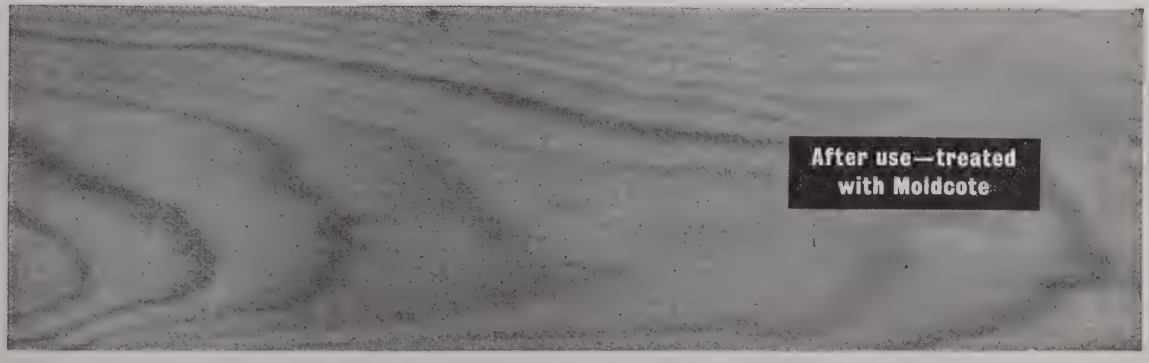

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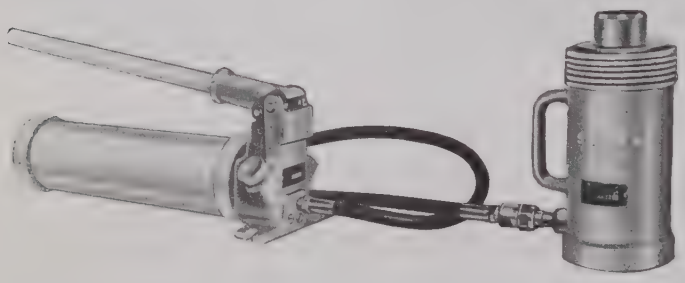

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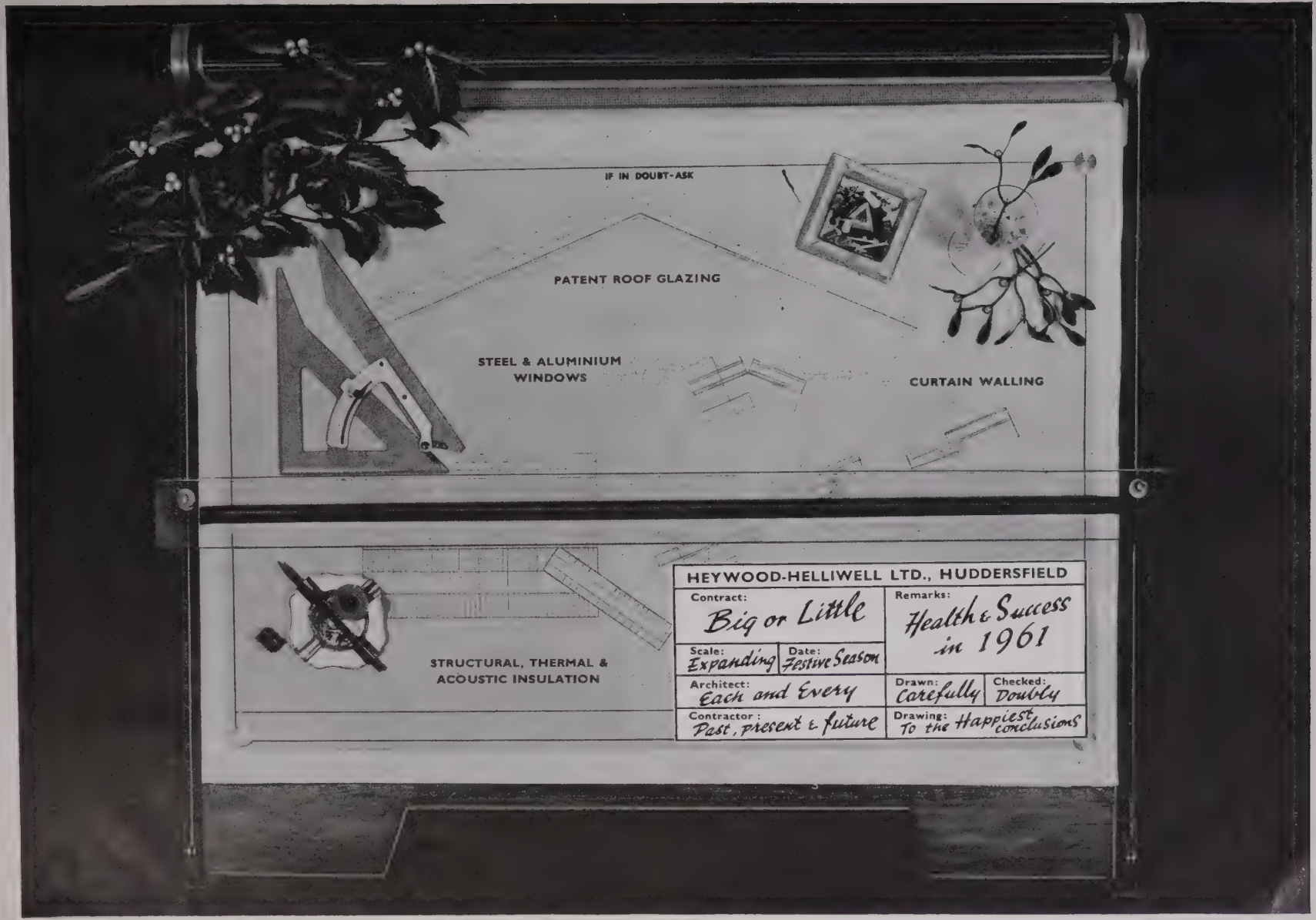
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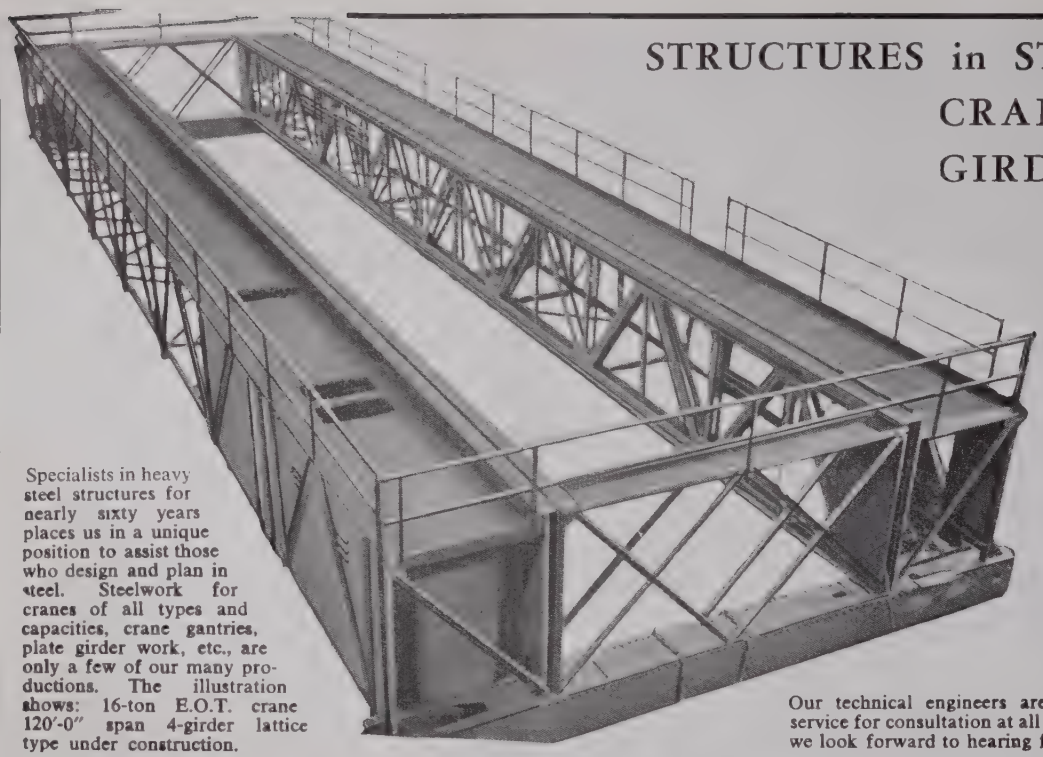

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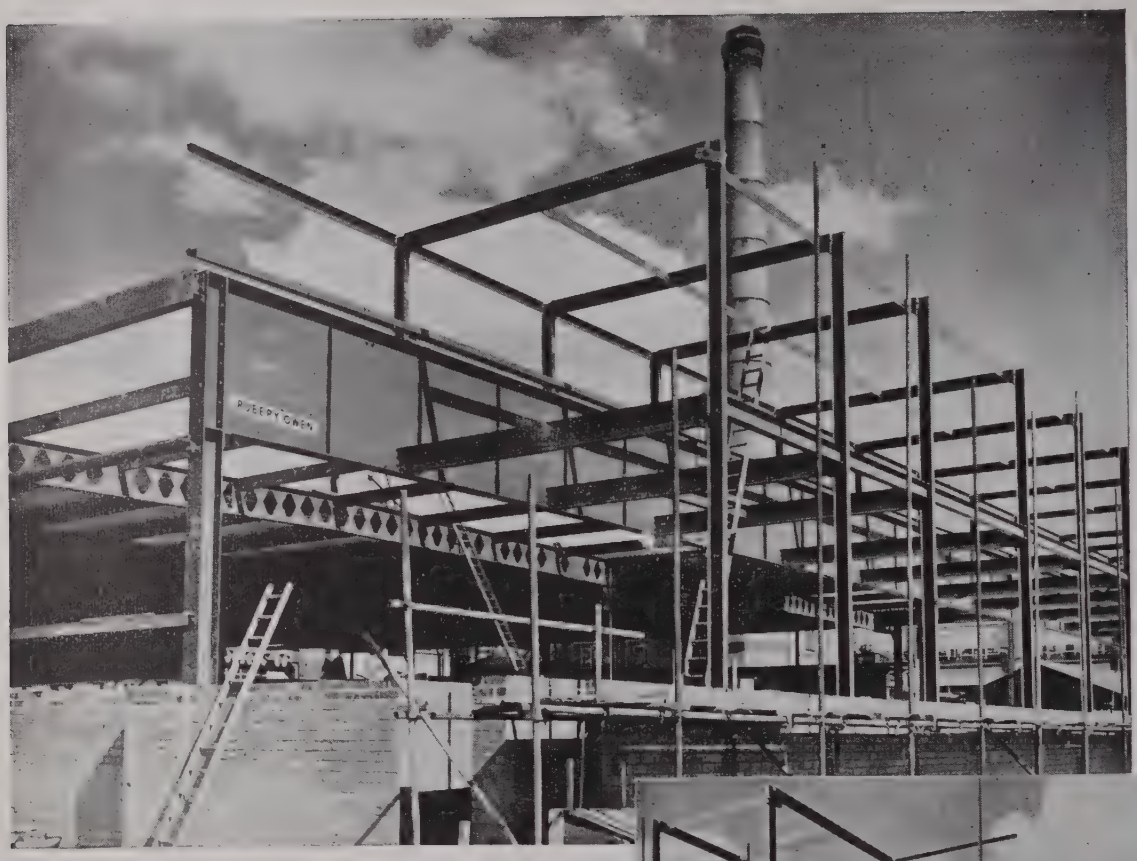

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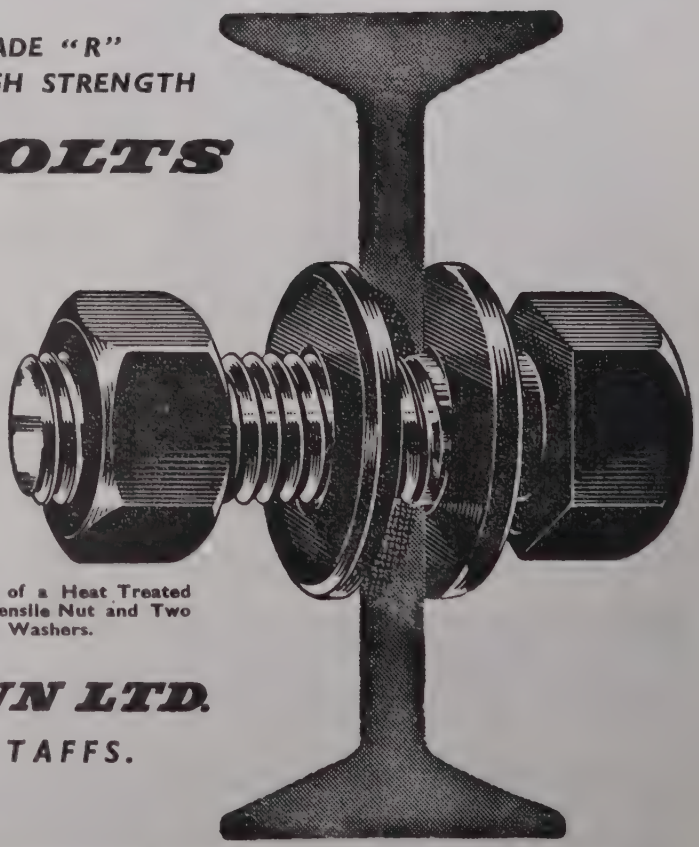

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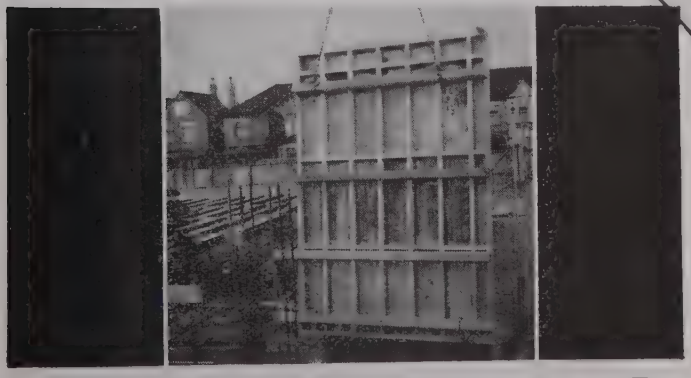

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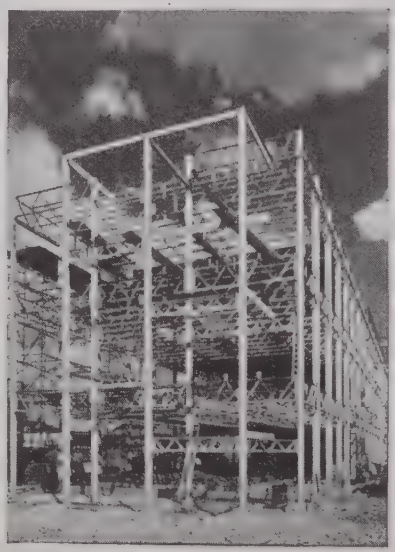

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Architect : E. Firth, F.R.I.B.A., A.M.T.P.I., City Architect.

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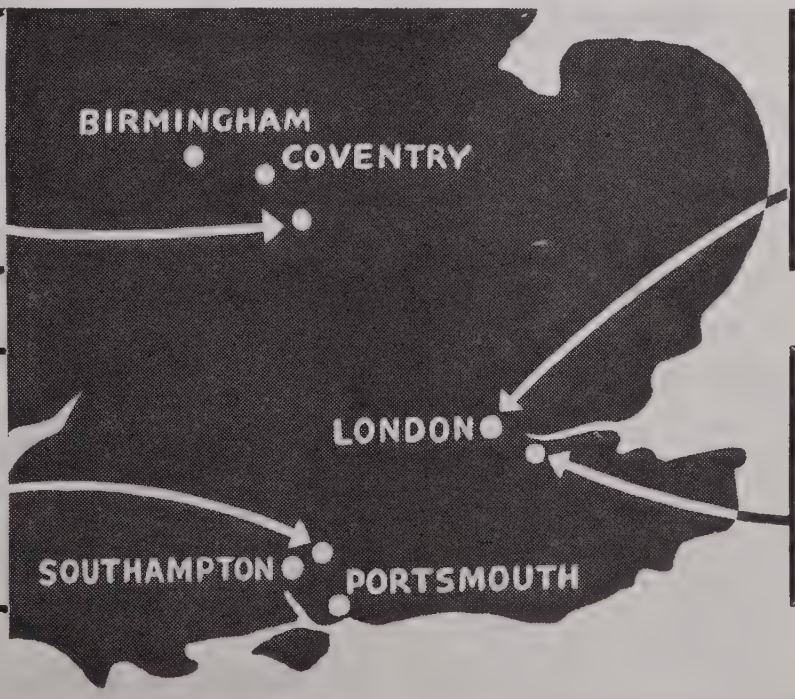

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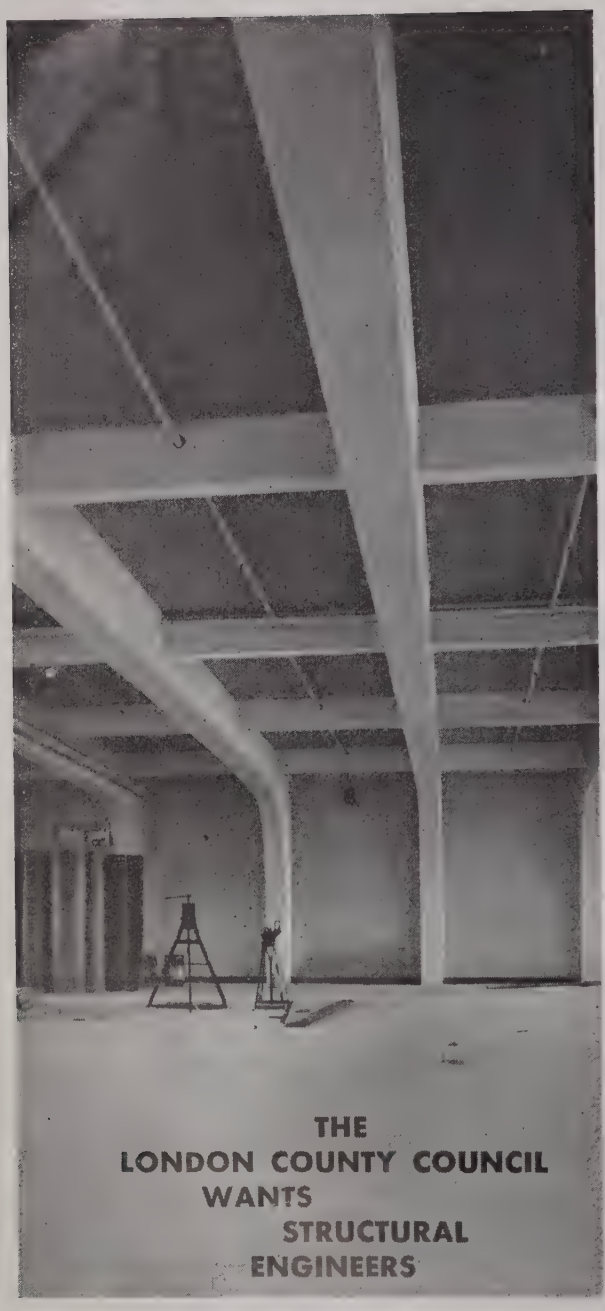

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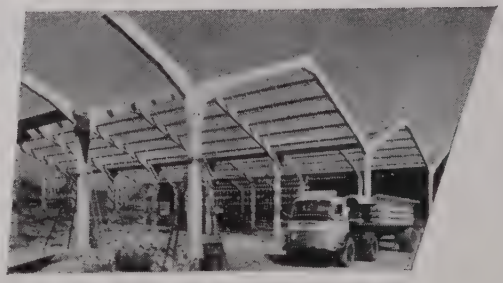

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OFFICIAL APPOINTMENTS

AIR MINISTRY Works Designs Branch requires in London Structural Engineering Designer Draughtsmen for reinforced concrete or structural steelwork of all types. Applicants must have adequate training and several years' experience. Some site experience and possession of recognised technical qualification an advantage. Financial assistance and time off may be allowed for recognised courses of study. Promotion and pension prospects. Five day week with 18 days paid leave per year initially. Salary ranges from £805 (at age 25) to £980 p.a. Commencing salary dependent on age, qualifications and experience. Applicants, who must be natural born British subjects, should write (quoting Order No. Kings Cross 3745) to Air Ministry W.G.d., Lacon House, Theobalds Road, London, W.C.1, or to any Employment Exchange giving age, details of training, qualifications, full particulars of former posts held and copies of any testimonials. Candidates selected will normally be interviewed in London and certain expenses reimbursed.

FEDERAL GOVERNMENT OF NIGERIA.—*Structural Engineer.* The Works Division of the Federal Ministry of Works and Surveys require a Structural Engineer to design and prepare structural engineering drawings for both reinforced concrete and structural steelwork, to design special reinforced foundations and reinforced concrete rafts, for all tpyes of buildings; to supervise structural engineering works on site and to prepare reports on structural defects in existing buildings. Candidates must be Corporate Members of the Institute of Structural Engineers and should have good general experience, especially in reinforced concrete, structural steelwork design and foundation design. The appointment will be on contract for one tour of 12 to 18 months in the first instance with good prospects of extension on a salary according to age and experience in the range of £1,434 to £2,196 p.a. plus a gratuity of £150 for satisfactory service. Candidates with more than two years post-graduate practical experience will enter the salary scale above the minimum. An outfit allowance of £60 is payable on all salaries up to £1,740 inclusive. Home leave on full pay. Free passages for officer and wife. Family allowances whilst separated. Income Tax at low local rate. Quarters at low rent. Candidates should write for application forms and further particulars, stating age, experience and qualifications, to the Appointments Secretary, Federal Public Service Commission, Nigeria House, 9, Northumberland Avenue, London, W.C.2, quoting V.14/1.

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quoting Ref. 60/6019

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OFFICIAL APPOINTMENTS—continued

STAFFORDSHIRE COUNTY COUNCIL

County Architect's Department

Applications are invited from suitably qualified candidates for the following posts :—

Structural Engineering Section

(a) *Senior Assistant Engineer.*—Grade Special/IV, commencing within the Special Grade (£840 to £1,145 p.a.), according to qualifications and experience. Applicants should be Chartered Structural or Civil Engineers with good experience in the design of structures in steelwork, reinforced concrete, and structural timber. Experience in the design of r.c. building frames an advantage.

(b) *Structural Draughtsman.*—Salary Scale A.P.T. II (£815 to £960 p.a.). Applicants should have good general knowledge of Structural Engineering and be neat and expeditious Draughtsmen. Duties include preparation of detail drawings in steelwork, reinforced concrete, and structural timber. Minimum qualifications required are graduateship of the Institution of Structural Engineers, or Higher National certificate.

The appointments will be subject to :—

(a) The National Scheme of Conditions of Service.

(b) The Local Government Superannuation Acts and the passing of a medical examination.

The County Council are prepared to grant a lodging allowance of 35s. per week to married applicants maintaining a home outside the geographical County for a period of six months, also second-class rail travel home every second month during the initial six months. The Council are also prepared to give consideration to the granting of financial assistance in appropriate cases towards removal expenses.

The Council has a scheme for loans to employees wishing to purchase their own houses.

Forms of application, which must be returned by the 30th November 1960, may be obtained from P. Woodcock, F.R.I.B.A., County Architect, Green Hall, Lichfield Road, Stafford.

T. H. Evans,
Clerk of the County Council.

SITUATIONS VACANT

A vacancy exists for an experienced R.C. designer/detailer or detailer/draughtsman. Good prospects; Varied and interesting work; Luncheon vouchers; Five day week. Apply with particulars of experience and salary required to John F. Farquharson & Partners, 34, Queen Anne Street, London, W.1.

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Ove Arup & Partners, 13, Fitzroy Street, London, W.1.

BYLANDER, Waddell & Partners have vacancies for designer/draughtsmen and draughtsmen with two years minimum experience of R.C. work. Modern office with pleasant working conditions and opportunities for advancement. Salary in accordance with experience. Apply 169, Wembley Park Drive, Wembley.

E. J. COOK & Co. (Engineers) Ltd., require reinforced concrete detailers and designer/detailers. Salaries according to ability and experience. Five day week; Luncheon vouchers; Pension scheme. Write or telephone for application form from 54, South Side, Clapham Common, S.W.4. (Tel.: MACaulay 5522).

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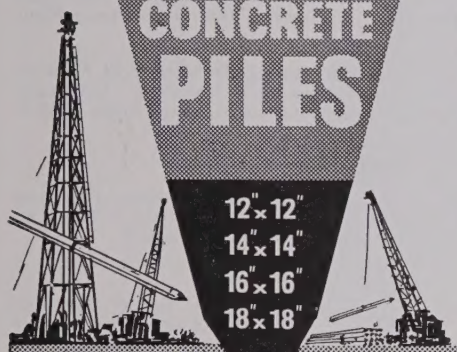

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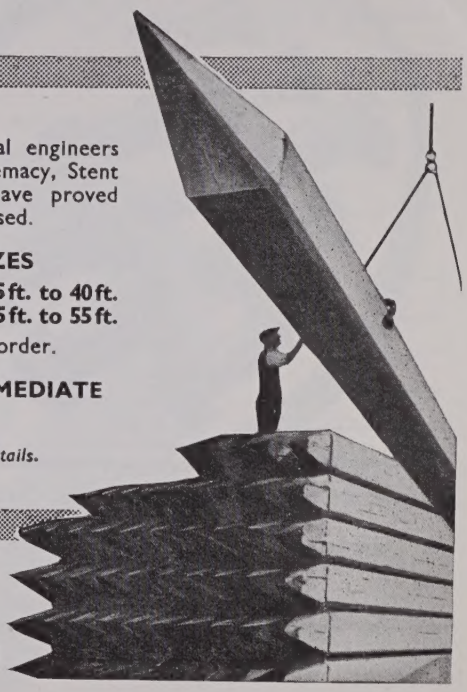

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SENIOR and Junior Draughtsmen required for reinforced concrete work. Five day week, non-contributory pension scheme and bonus in operation. Apply to Indented Bar & Concrete Engineering Co. Ltd., 171, Victoria Street, London, S.W.1. (Adjacent Victoria Station).

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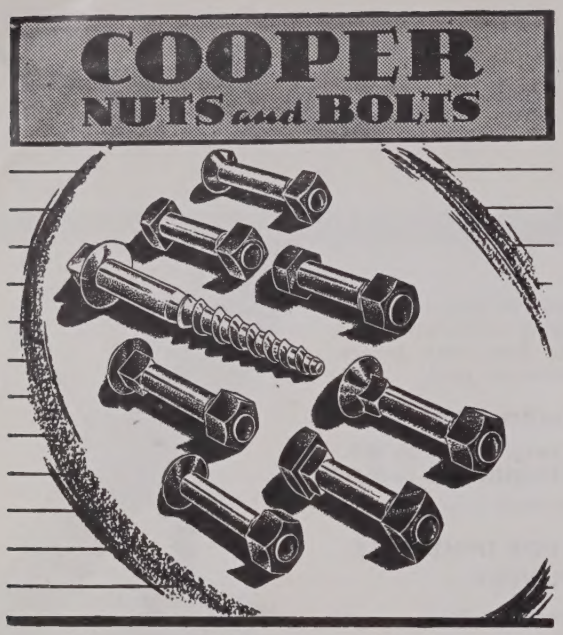

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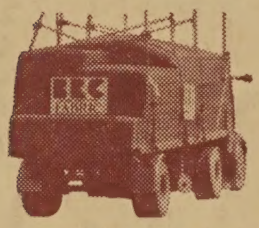

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